General Introduction

This memorandum deals with the principles of applying traffic engineering techniques to urban road traffic problems. It stresses the need for making preliminary studies before any traffic or parking survey is planned, explains how many types of surveys can be undertaken and their results presented and then shows how these results can be used for the formulation of proposals.

It would be desirable, particularly in larger towns, to have a comprehensive study of the land use and transport problems of the town prior to the introduction of traffic engineering measures, so that all such measures can be seen to be part of a phased programme of improvement to both the town's transport facilities and its environment. Nevertheless in many towns it will be necessary to proceed with urgent schemes before the land use/transport surveys, recommended by Joint Circular No. 1/64* and the Buchanan report,† have been completed, the results analysed, policies decided and plans prepared.

This memorandum is designed to enable suitable short to medium term solutions to be found for urgent traffic problems and at the same time provide a useful guide to the wide range of traffic engineering methods and techniques, many of which will need to be used in the formulation of the long-term traffic solutions which will be incorporated in comprehensive land use/transport plans. This memorandum does not attempt to give guidance on the surveys needed for preparing these plans: this advice will be issued later.

The shorter-term traffic solutions should not be looked at in or by themselves. They should be viewed as far as possible in relation to parking policies, to the needs of environmental as well as traffic management, and to the likely ultimate pattern of town roads. In all this they have a big part to play and, in turn, they are affected by these other considerations. Together they make up the broad approach to the problem of traffic in towns. In particular, for example, any short-term proposal which would determine road widths or alignments for a long time ahead should be carefully considered in this wider context.

This memorandum has been prepared by a technical committee representing the Ministries of Transport and of Housing and Local Government, and the Road Research Laboratory, whose terms of reference were 'to prepare for the guidance of local authorities a memorandum on techniques for the investigation of urban traffic problems, on means which can be used for the improvement of traffic flows and safety, and methods of assessing the relative merits of such means'.

Representing these departments on the Technical Committee at various times were:

- Mr W.F. Adams, B.Sc, (Eng), M.I.C.E. (Chairman) (Ministry of Transport)
- Mr H.N. Ginns, B.Sc, (Eng), M.I.C.E. (Chairman) (Ministry of Transport)
- Mr G.C. Booth, B.Sc, (Eng), A.C.G.I, D.I.C, M.I.C.E, A.M.T.P.I, (Ministry of Housing and Local Government)
- Mr J.P.F. Kacirek, A.R.I.C.S, A.M.T.P.I, (Ministry of Housing and Local Government)
- Dr R.J. Smeed, B.Sc, Ph.D, F.S.S, (Road Research Laboratory)
- Dr G. Charlesworth, B.Sc, Ph.D, F.Inst.P, A.M.I.C.E. (Road Research Laboratory)
- Mr J.G. Wardrop, B.A, F.S.S, (Road Research Laboratory)
- Mr J.T. Duff, M.Sc, A.M.I.C.E, A.M.I.E.E, (Ministry of Transport)
- Mr. D.E. Dyas, A.M.I.C.E, (Secretary) (Ministry of Transport)

The Committee have consulted with many organisations and bodies interested in traffic engineering and wish to record their appreciation of the helpful advice received. Those consulted were:

- The Association of Chief Police Officers
- The Association of Metropolitan Borough Engineers
- The British Road Federation
- The County Surveyors' Society
- The Institution of Civil Engineers
- The Institution of Highway Engineers
- The Institution of Municipal Engineers
- The Standing Joint Committee of the R.A.C, A.A, and R.S.A.C. – and
- The Town Planning Institute.

The Memorandum has been divided into seven parts and each of parts 1–6 covers a particular stage in the process of investigating and dealing with urban traffic problems. It is recommended that the whole document is studied before proceeding with specific projects so that the relevant parts can be noted.

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* Circular No. 1/64, Ministry of Housing and Local Government, Circular No. Roads 1/64 Ministry of Transport (Her Majesty's Stationery Office, 8*d*).

† Traffic in Towns, a study of the long-term problems of traffic in urban areas (Her Majesty's Stationery Office, price 50*s*).

The parts and scope of each part are detailed below:

PART 1 PRELIMINARY STUDIES – A preliminary reconnaissance in order to identify the nature of traffic problems, the information available on traffic data, accidents and land uses and the extent to which further information is needed.

PART 2 ORGANISATION AND CONDUCT OF TRAFFIC AND PARKING SURVEYS – Methods of taking traffic censuses, origin and destination surveys, surveys of public transport, speed measurements, parking surveys and collecting accident data.

PART 3 ANALYSIS AND PRESENTATION OF SURVEY RESULTS AND OR ACCIDENT DATA – The processing and presentation of survey information ready for formulating schemes.

PART 4 FORMULATION OF PROPOSALS – The design of short, medium or long term schemes to meet the needs of both traffic and road safety.

PART 5 ASSESSMENT OF RELATIVE MERITS OF ALTERNATIVE SCHEMES – Methods for comparing the advantages and disadvantages of alternative proposals including the economic assessment of road improvements.

PART 6 FOLLOW-UP STUDIES – The studies needed to check up on the adequacy of the measures taken and to reveal any need for further measures.

PART 7 CONCLUSION – The value of quantitative assessment of traffic problems and improvement schemes, the need to study and train engineers in the methods of meeting traffic requirements and to take advantage of new or little used techniques.

PART 1

Preliminary Studies

Introduction

1. The first stage in studying traffic problems of an area should be to make a preliminary reconnaissance. This in turn will enable decisions to be made as to the extent and nature of the traffic surveys which will have to be carried out. The preliminary reconnaissance should also include an examination of existing data on land use, traffic and accidents, since this will not only help in identifying the problems but will also generally enable economies to be effected in the subsequent survey work.

2. The amount of preliminary reconnaissance required will depend on the size of the area and the local knowledge of those entrusted with the task. The following procedure which may be adapted according to circumstances is suggested:

Preliminary Survey

3. The main streets in an area should be toured both by car and on foot and impressions formed of the traffic conditions on them. The tour should be made during the morning and evening peaks and at other times of the day and also on different days including week-ends depending on the form of the problem. Particular note should be made of intersections at which delays are experienced, streets where parking or loading and unloading interferes with traffic flow, and points where pedestrian flows obstruct traffic or conditions appear dangerous. A note should also be made during this survey of the land uses in the area (particularly of any buildings which appear to be large generators of traffic and parking) and the degree of ripeness for redevelopment at points where major traffic congestion is observed.

4. The effect on congestion and delays of natural barriers such as rivers, hills and railways which concentrate traffic at a few strategic points should also be borne in mind.

5. Finally a general impression should be formed of the extent to which the various traffic engineering methods referred to later in this bulletin have already been employed and with what success.

Consultation with Other Authorities

6. Discussions should take place with:

(a) The police official responsible for traffic control in the area, again with the object of identifying the places where difficulties occur and the nature of these difficulties, and the extent to which he may be able to provide assistance in carrying out the subsequent survey.

(b) The Transport Manager or other official responsible for the routeing of public services (including railways where appropriate). Information should be obtained on the pattern of bus routes, the frequencies of services during peak and off-peak periods and on the siting of stops. An impression should also be formed of the adequacy of services during peak times.

(c) The motoring associations, local chambers of commerce and any other bodies who may be concerned with the traffic problem and may be expected to have views on the possible solutions.

(d) The Planning Officer responsible for the general planning of the town. Information on the needs of traders for facilities for loading and unloading should be obtained.

Scope of Existing Data

7. Following the preliminary survey of the area and discussions with the various officials the examination of existing data should be made. Such data will be of two kinds, local data collected at different times in the past and for a variety of purposes, and national data which may be useful for evaluating the local data and for reducing the amount of subsequent survey required.

Traffic Counts which may be available are:

8.(i) Those taken at particular intersections in connection with proposals for control by traffic light signals, construction of roundabouts, etc. These counts will often be in the standard form described in the next part;

(ii) Those taken on individual streets for various purposes, for example, in connection with proposals for waiting restrictions;

(iii) Those taken on main roads entering the town either as part of an origin and destination survey or as part of a national traffic census. The latter is referred to in more detail later in this part.

9. As any information that is relevant to the area will most probably have been collected in different years and at different times of the year as well as for varying periods of the day, it will seldom be possible to weld it together into a consistent and comprehensive traffic picture. Its use will more commonly be for assessing the scale of the problem and for deciding where and to what extent subsequent counting is required. Counts which have been taken at the same site in different years may be useful for assessing the growth rate for the town.

Pedestrian Counts

10. These may have been taken in connection with proposals for pedestrian crossings or traffic signals and will usually relate to peak periods either for pedestrians or traffic or both. It is comparatively rare for pedestrian counting to be done in any systematic or consistent manner and it is unlikely therefore that any comprehensive picture can be formed from existing data.

Origin and Destination Surveys

11. An external or internal origin and destination survey may have been taken which throws light on traffic flows in or near the area being studied. Such surveys, relating to a specific proposal, will usually be found to be inadequate for the present purpose and, if taken too long ago, may not adequately reflect current conditions.

12. Nevertheless, where such a survey has been made, the results should be carefully studied to see whether further analysis of the field data would be useful or whether any of the results can be used to cut down the amount of work involved in carrying out new surveys. It could in any case be of value in the planning of any new survey, as it would indicate the volumes of traffic which might have to be handled if the new survey requires the use of similar techniques and it will indicate practical difficulties. It may also furnish a useful guide as to the manpower requirements, cost and time needed to take and analyse a new survey.

Parking Surveys

13. These may have been made in individual streets in connection with proposals for waiting restrictions and some towns will already have undertaken a comprehensive survey of the numbers of parked vehicles and durations of parking both on the streets and in surface parks and garages off the streets.

14. Where such study has been made the results should be examined to ensure that the area covered is adequate and that no items of essential information have been missed (see next part). Surveys in individual streets are likely to be useful mainly in deciding on the manpower required for comprehensive surveys and on days and times suitable for carrying them out. It will seldom be advisable to omit such streets from a new survey.

Speed and Delay Studies

15. These studies have not been very common in the past, particularly in the smaller towns, and it is unlikely that existing data will be available. The preliminary reconnaissance, if made by car, will, however, give useful guidance in planning such studies. Some useful information is often obtainable from the operators of Public Service Vehicles.

Accident Studies

16. Studies of accidents at particular sites may have been made as a result of complaints or known dangerous conditions. Such studies will be of considerable value in confirming or otherwise impressions gained during the preliminary reconnaissance. It is possible, however, that accidents have been studied in a more systematic manner, with a view to discovering all the black spots and for assessing the value of the various remedial measures which are subsequently carried out, in the way described in Circular No. 734 issued by the Ministry of Transport to local authorities. The system of recording recommended in this Circular enables a continuous watch to be kept on the accident position by showing in graphical form the sites at which accidents occur and ensures a permanent record for assessing the results of measures carried out. A modified method for urban areas is described in paras. 180–190.

Land Use Studies and Development Plans

17. Land use and other surveys undertaken in connection with the preparation of a statutory Town Map or of Town Centre or other maps prepared, for their own purpose, by the local planning authority or local authority, can be of great assistance. Detailed land use, population, employment, building density and the age and condition of buildings in and around the area can be found from these surveys: some or all of this information would be relevant to assessing the causes of local traffic problems and deciding on the most effective remedies.

National Data

18. National data, with the exception of traffic counts taken locally as part of the comprehensive census of August, 1954 and the Trunk Road census in 1961 are of use mainly in providing a standard of comparison for local figures and in providing correction factors to be applied to local data as explained later. The counts taken in 1954 covered nearly 6,000 points on all the important trunk and Class I roads in Great Britain and for the 1961 census nearly 1,500 points. Traffic was counted for seven consecutive days in August during the hours 6 am to 10 pm (at some of the more important points the counts were continued during the night hours). The more important categories of motor vehicles and pedal cycles were recorded separately hour by hour. The census points were, in the main, outside the built-up areas of towns but valuable information for local purposes may be obtained from points on the outskirts of

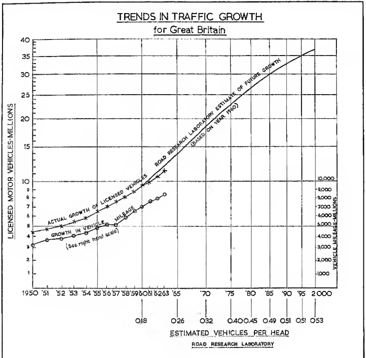


FIG I

towns. The details for individual points may be obtained from the highway authority which took the count or from the Divisional Road Engineer of the Ministry of Transport, or the Chief Road Engineer, Scotland.

19. An annual census is organised by the Ministry of Transport in conjunction with the Scottish Development Department at 132 points on trunk and Class I roads (100 in England and Wales, 32 in Scotland) in August of each year. These counts started in August 1956. They cover seven consecutive days during the hours 6 am to 10 pm and the more important categories of vehicles and pedal cycles are separately recorded. The points have been chosen in such a way that estimates of the vehicle miles travelled during the week of the census can be made. With so few points it is unlikely that individual results will be available for a given town.

20. The results of these counts for England and Wales are published in the annual reports on roads in England and Wales, which are obtainable from Her Majesty's Stationery Office. A comparison with earlier years is given for each class of vehicle for the various engineering divisions of the Ministry of Transport. These figures can be used to compare local traffic growth with that which has taken place regionally or nationally or where no local figures are available they can be used as a means of correcting earlier traffic counts to current levels. Since there are considerable local variations in traffic growth these figures must be used with some caution and early consideration should be given to the setting up of a series of annual local counts which will provide a more reliable picture of the trends in local traffic. Care is required in the choice of sites for determining the local growth of traffic, bearing in mind the changes in traffic pattern which take place when congestion on main routes increases.

21. Since January, 1956 a series of continuous counts with automatic counters has been organised by the Road Research Laboratory at 50 points throughout Great Britain on trunk, Class I, Class II and Class III roads. Estimates of the vehicle miles travelled on each of these classes, separately for urban and rural areas, are furnished on a monthly basis. More recently these counts have been supplemented by sample monthly manual counts which provide estimates of the vehicle miles travelled by the various classes of vehicles. The national growth of travel (measured in passenger car units) has of recent years been at the rate of 5% per year compound and in the absence of known local factors it is recommended that estimates should be based on this rate of growth. For long term improvements it is considered desirable to look towards the growth over a 20–25 year period. In this connection reference should be made to the latest available estimates on vehicle ownership and traffic growth. The estimates made by the Road Research Laboratory for vehicle growth and car ownership relating to Great Britain as a whole are shown in Fig 1, these take into account forecasts of increase in population made by the Government Actuary's Department in consultation with the General Register Office and Registrar-General for Scotland. It should always be borne in mind that when a road is widened or a new road constructed in a built up area, further improvement may well be precluded for the next 50–60 years by the erection of buildings alongside the road. This being so, it is desirable to look beyond the 20–25 year period to ensure that the road proposals are compatible with longer term development proposals for the town as a whole.

22. A table of monthly index numbers for traffic flow is published in the Monthly Digest of Statistics. These numbers can be used to correct counts made in another month to the August level. For convenience the index numbers for the period 1959–1962 for roads in urban areas are given in Table 1. In certain locations, e.g. industrial areas, this table may not be applicable and it will then be necessary to determine the local index number for each month of the year (see paragraph 35).

Table 1: Urban Traffic Flow as a Percentage of the August Level (1959–1962)

(based on a standard week in each month)

Month	
January	72
February	79
March	84
April	85
May	93
June	98
July	99
August	100
September	97
October	91
November	86
December	82
Average for year	89

23. Origin and destination surveys taken in this country in the period 1959–1962 show that there is great variation in the percentage of non-stop traffic in a town of a given population. Results of these surveys shown in Fig 2 indicate the difficulty of correlating by-passable

traffic with population but it will be seen that a rough estimate can be made of minimum percentages.

24. Tables of national accident statistics are published annually by the Ministry of Transport and Scottish Development Department and may be obtained through Her Majesty's Stationery Office. These statistics are mainly of value for comparison with local statistics. Such comparisons can be made either in the proportions of casualties of a given kind, for example the proportion of pedestrian casualties occurring in the town can be compared with the national proportion, or in the increase over a given period.

Plan of Preliminary Studies

25. It is suggested that the results of these preliminary studies should be summarised on an overlay tracing of a map of the town. This will help in the organisation of the comprehensive traffic and parking survey as described in the next part.

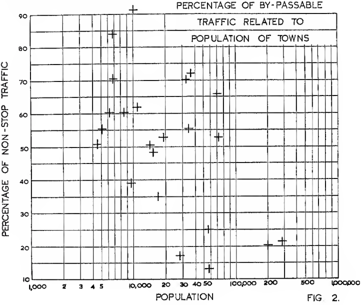


FIG 2.

PART 2

Organisation and Conduct of Traffic and Parking Surveys

Introduction

26. The production of the best proposals for dealing with traffic problems must depend upon an adequate knowledge of the pattern of traffic movements. For a survey which covers a wide area or which could be incorporated in a later comprehensive land use/transport survey early consideration should be given to the possible use of punched card or tape machines. If it is decided to use such machines the work should be planned from the outset with this in mind in consultation with the person in charge of the machines. The preliminary studies, carried out as recommended in Part 1, will have shown what additional surveys are needed and may help to determine the manpower required for such survey. Part 2 deals in more detail with the various studies that may be required, with the methods available for collecting the necessary information and gives examples of standard forms which are suitable for the purpose. The analysis of this information is dealt with in Part 3.

Definitions

27. The term *census* is generally reserved for the simple counting of numbers of vehicles or pedestrians. The various classes of vehicles, such as private cars, motor cycles, etc., may be separately counted and the vehicles may be moving past a census point as in the usual *volumetric census* or stationary in a given area as in a *parking census*. The vehicles may also be classified according to the direction which they take at an intersection as in a *distribution census*.

28. A *manual census* is one in which the counting is done by enumerators with tallies, printed forms or note books whilst an *automatic census* is one in which the counting is done by mechanical apparatus.

29. The term *survey*, on the other hand, is generally reserved for the type of study which, in addition to counting, seeks to classify vehicles according to some characteristic other than class of vehicle or distribution at an intersection which have been referred to above. In an *origin and destination survey* vehicles are classified as local or through, long distance or short distance or into streams between various zones of origin and destination. A *parking survey* may seek for example to classify vehicles according to the length of time for which they park, or relate them to land use.

30. The speeds of vehicles may be measured as spot speeds, journey speeds or running speeds. The *spot speed* is intended to represent the instantaneous speed as the vehicle passes a given point on the road although in practice the measurement has to be made over a finite length of road which may vary from some two feet to several hundred feet according to the method used. Journey speeds and running speeds are measured basically in terms of the times taken to traverse a given section of road. It is frequently more convenient to use the times rather than the speeds calculated from them. The *journey time* is the overall time taken to travel between two specified points on a route, excluding the times of any stoppages other than those due to interruptions of traffic. The *stopped time* is the time spent stationary on a journey as a result of the requirements of other traffic whilst the *running time* is the difference between the journey time and the stopped time.

31. The *design speed* of a road is the speed used for correlating the various design features to give a uniform standard of comfort and safety in driving along it.

32. The *delay* experienced by a vehicle is the time during which it is impeded in its movement by some element over which it has no control. It includes in addition to the stopped time any time lost travelling at very low speed and the time lost in decelerating and accelerating.

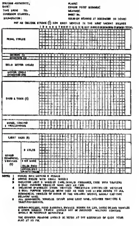
Traffic Censuses Generally

33. Information from traffic censuses is required for many purposes but which may be summarised into two groups, viz:

(a) *Peak hour flows and distribution* either along roads or at junctions for determining the necessary road or junction capacity which must be provided. Unlike rural roads which are designed on the total flow in one day, urban roads require to be designed on the basis of peak hour demands.

(b) *Average hourly flows throughout the year* for determining the economic assessment of new or improved roads and junctions and also the assessment of accident statistics on a road in relation to the accident rate per million vehicle miles.

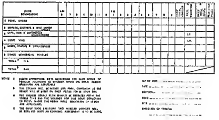
34. As the count or counts for a census may be taken at any particular time of the year or day of the week for both of the above purposes allowances must be made to determine the average week day peak flow on the heaviest month of the year and also to estimate the average hourly flow for the whole year from a particular traffic count. It is desirable to exclude peaks due to special local events, bank holidays, etc.



ENUMERATOR'S FORM
FIG 3

35. For the purpose of determining the heaviest month of the year or the average flow throughout the year the national data (see paras 18–22) are usually adequate but if local data are required it would be necessary to use an automatic counter for the whole year taking readings at, say, weekly intervals supplementing this information by sample counts of vehicle types. Automatic traffic counters are of two main types, those which record the number of vehicles passing in a given time (usually every hour or every quarter hour) and those which give a simple cumulative total which must be read when required. Both types are operated by the passage of a vehicle over a detector fixed across the carriageway and one unit is registered for the passage of two axles. The possibility of mechanical failure should be borne in mind and regular inspections made.

36. Where counts have been made only for one day or period of a day, in addition to scaling up the volumes obtained to correspond with the peak month it will often be necessary to compare these flows with those obtained for the same times of the day at comparable sites where a full census has been taken. This will enable an estimate to be made of the average peak-hour flow occurring during the week or if required the average weekly flow. It is generally assumed that flow patterns on weekdays, Monday to Friday (excepting market days or early closing days) are similar.



HOURLY RECORD FIG 4

FORMS FOR RECORDING & ANALYSING TRAFFIC FLOWS ON A ROAD

37. The various ways of obtaining more comprehensive censuses are described below:

38. A count made for seven consecutive days from 6 am to 10 pm classifying traffic as to types. The forms shown in Figs 3 and 4 are appropriate for these purposes.

39. As above – but limited to the hours 8 am to 8 pm, adjusted if necessary where peak flows commence before 8 am.

40. As above but limited to Friday, Saturday and Sunday or Saturday, Sunday and Monday. The average daily flow would then be:

$$\frac{5 \times \text{Weekday} + \text{Saturday} + \text{Sunday}}{7}$$

41. If Friday or Monday is an abnormal day (e.g. market day or early closing day) the count should be extended to include a normal weekday and weekly average is then:

$$\frac{4 \times \text{Weekday} + \text{Market Day} + \text{Saturday} + \text{Sunday}}{7}$$

42. Fig 3 shows a typical form for a manual count. The vehicle classification represents about the maximum that can be reasonably undertaken by one enumerator and for some purposes fewer classes are sufficient. The classification should not be more complicated than is required and the standard form should be suitably amended before issue to the enumerators. Sufficient information is only required to evaluate the passenger car unit values appropriate to the purpose of the census. With the form shown a normal enumerator can deal with about 600 vehicles per hour (or for short periods up to 800 vehicles per hour). Greater volumes can be counted by devices such as hand tally counters to record the volume of private cars and the form for the remaining classes of vehicles or by employing two enumerators counting different classes of vehicles. It is usual to start a fresh form every hour so that hourly variations in traffic flow are easily determined. The form shown in Fig 4 summarises the results collected by the enumerator and enables pcu conversion to be made – see para 54.

Traffic Censuses for Road Junctions

43. A typical form for taking a distribution count at an intersection is shown in Fig 5, one form used for each hour for each approach. At busy intersections a bank of hand tally counters may be used, each arm of the intersection being counted separately. The results should be summarised on a form as shown in Fig 6 from which the calculations into pcu's are made on form Fig 7.

44. This count may be for a full day, 8 am to 8 pm but as it is essential to include both peak hours of the day it may be necessary in some instances to vary these times to, say, 7.30 am to 7.30 pm.

45. In some cases sufficient information will be obtained by limiting counts to periods of 1½ to 2 hours at morning and evening peaks or exceptionally include a mid-day peak count. Separate field sheets should be used for each half hour in such circumstances. Where counts are to be used to determine signal settings at complex junctions an off peak count is often required in addition. The peak flows obtained will require adjustment for the monthly index so as to obtain the maximum flows during the year.

46. For complicated intersections where it is not possible to judge quickly which exit a vehicle is likely to take two methods of counting are available:

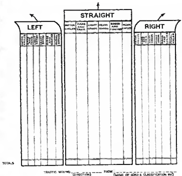
47. If a high vantage point is available giving a complete view of the intersection a sample of vehicles may be traced from each approach by one observer whilst a second counts all the vehicles entering on that approach. The total vehicles counted are then allotted to each exit in the proportions formed from the sample. It is obviously important that the sample of vehicles shall be representative. For example if vehicles approach in two or more lanes the near side lane may contain an undue proportion of left turning traffic, and any attempt to concentrate on the slower vehicles may lead to an incorrect distribution. It is therefore necessary for a procedure to be decided in advance and followed strictly by the enumerator throughout the count. One method is for the enumerator after noting a previous entry to then select the first vehicle to cross a stop line or similar road marking.

48. If no vantage point is available the registration numbers of a sample of vehicles entering or leaving the intersections may be taken and the results matched to give the distribution. This method is, however, expensive in manpower since every entry and exit must be manned simultaneously. The sample is obtained by recording numbers ending in a given digit or digits, e.g. recording only registrations numbers ending in 2 or 7 gives a one-fifth sample of the total. In deciding the fraction to be sampled it should be borne in mind that errors in recording and the missing of vehicles at entry or exit will result in losses of matched pairs.

For Road Improvements

49. Whilst peak-hour flows may often be provided by census information obtained for road junctions, in other instances a peak-hour census similar to that described for road junctions will be adequate for most improvement schemes. On large schemes a full census such as described in paras 38–42 is desirable so that a more reliable economic assessment may be made.

50. For less important roads where a general index of traffic flow is required a count of 100 vehicles may be taken and the flow calculated from the time taken for these vehicles to pass. An estimate on this basis would give an accuracy for an hour's count of ±20% for



	LEFT						STRAIGHT						RIGHT					
	MOTOR CYCLES	CARS AND TAXIS	LIGHT GOODS	HEAVY GOODS	BUSES AND COACHES	PEDAL CYCLES	MOTOR CYCLES	CARS AND TAXIS	LIGHT GOODS	HEAVY GOODS	BUSES AND COACHES	PEDAL CYCLES	MOTOR CYCLES	CARS AND TAXIS	LIGHT GOODS	HEAVY GOODS	BUSES AND COACHES	PEDAL CYCLES
TOTALS																		

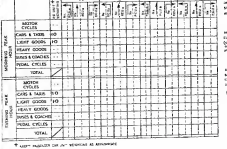
TRAFFIC MOVING .... (DIRECTION) (N.S.E.W.) .... FROM .... (NAME OF ROAD & CLASSIFICATION No)

NAME OF AUTHORITY ....
COUNTY ....
JUNCTION ....
DAY OF WEEK ....
DATE ....
WEATHER ....
ENUMERATOR ....
HOUR from .... M. to .... M.

NOTE ONE SHEET FOR EACH APPROACH TO THE JUNCTION WILL BE REQUIRED FOR EACH HOUR OF THE CENSUS.

ENUMERATOR'S FORM

FIG 5



			ENTERING JUNCTION FROM																							
			A						B						C						D					
		PC UNIT + WEIGHTING	← No.	← PCUs	↑ No.	↑ PCUs	→ No.	→ PCUs	← No.	← PCUs	↑ No.	↑ PCUs	→ No.	→ PCUs	← No.	← PCUs	↑ No.	↑ PCUs	→ No.	→ PCUs	← No.	← PCUs	↑ No.	↑ PCUs	→ No.	→ PCUs
MORNING PEAK HOUR	MOTOR CYCLES	- -																								
	CARS & TAXIS	1·0																								
	LIGHT GOODS	1·0																								
	HEAVY GOODS	- -																								
	BUSES & COACHES	- -																								
	PEDAL CYCLES	- -																								
	TOTAL																									
EVENING PEAK HOUR	MOTOR CYCLES	- -																								
	CARS & TAXIS	1·0																								
	LIGHT GOODS	1·0																								
	HEAVY GOODS	- -																								
	BUSES & COACHES	- -																								
	PEDAL CYCLES	- -																								
	TOTAL																									

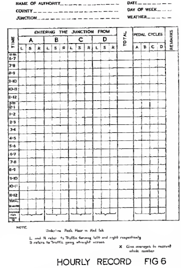
+ INSERT PASSENGER CAR UNIT WEIGHTING AS APPROPRIATE

DAY OF WEEK ....
DAY ....
SITE ....
WEATHER ....

MORNING PEAK HOUR .... AM
EVENING PEAK HOUR .... PM
(Now the midday peak may justify an additional statement at Amh place)

A ....
B ....
C ....
D ....
(Insert name of road and direction of traffic)

PEAK HOUR DISTRIBUTION SHEET FIG. 7



SUMMARY SHEET ~ VEHICLES

NAME OF AUTHORITY .... DATE ....
COUNTY .... DAY OF WEEK ....
JUNCTION .... WEATHER ....

TIME	ENTERING THE JUNCTION FROM												TOTAL	PEDAL CYCLES				REMARKS
	A			B			C			D								
	L	S	R	L	S	R	L	S	R	L	S	R		A	B	C	D	
am 6-7																		
7-8																		
8-9																		
9-10																		
10-11																		
11-12																		
pm 12-1																		
1-2																		
2-3																		
3-4																		
4-5																		
5-6																		
6-7																		
7-8																		
8-9																		
9-10																		
10-11																		
11-12																		
TOTAL 18 HOURS																		
AVERAGE PER HOUR X																		

NOTE.

Underline Peak Hour in Red Ink

L and R refer to Traffic turning left and right respectively
S refers to Traffic going straight across

X Give averages to nearest whole number

HOURLY RECORD FIG 6

FORMS FOR RECORDING AND ANALYSING TRAFFIC FLOWS AT A ROAD JUNCTION volumes up to about 1,000 vph. For volumes of 250 vph or less, the sample size can be reduced to 70: for volumes less than 100 it can be reduced to 50 vehicles. For other degrees of accuracy the sample to be counted should be:

$$\frac{40{,}000}{x^2 + \frac{40{,}000}{V}}$$

where x=percentage accuracy and V=vehicles per hour.

51. Where there are variations in flow other than random over the hour this method of sampling should be used with discretion.

Table 2: Vehicular ratings in passenger car units

Class of Vehicle	Equivalent value in passenger car units (pcu's)			
	Rural Standards	Urban Standards	Roundabout Design	Traffic Signal Design
Motor cycle combinations, private cars, taxis and light goods up to 30 cwt unladen	1·00	1·00	1·00	1·00
Motor cycles (solo), scooters and mopeds	1·00	0·75	0·75	0·33
Goods vehicles over 30 cwt unladen and horse-drawn vehicles	3·00	2·00	2·80	1·75
Buses, coaches, trolley vehicles and trams	3·00	3·00	2·80	2·25
Pedal cycles	0·50	0·33	0·50	0·20

52. For by-passes and roads in outlying areas where rural standards of design are applicable (see memorandum 780) then the road design should be based on the average daily flow and a census such as outlined in paras 38–42 will be required.

53. In all cases adjustments should be made to the volumes obtained by means of the monthly index so as to correspond with flows at peak times of the year.

Passenger Car Units (pcu's)

54. Vehicles of different types require different amounts of road space because of variations in size and performance. In order to allow for this in capacity measurements for roads and junctions, traffic volumes are expressed in passenger car units (pcu's). The basic unit is a car (Taxis, light vans or three-wheeled vehicles are also one unit). As different types of vehicles affect the capacity of rural roads, urban roads, roundabouts and traffic signals in varying degrees the weighting for each class of vehicle has to be varied to suit the purpose for which they are to be used. For example, a heavy goods vehicle on a rural road may be rated as equivalent to 3 cars but on an urban road only 2 and at traffic signals 1·75. The appropriate values for different types of vehicles under varying conditions are given in Table 2.

Pedestrian Counts

55. Counts of pedestrians moving along a road may be required in order to determine the width of footpath necessary or in connection with proposals for continuous lengths of pedestrian guard rail. More usually, however, counts are required of the number of pedestrians crossing the carriageway at, or near, specific points. These latter counts may be for the provision of pedestrian facilities, such as zebra crossings, signalled crossings, footbridges or subways or to allow for the possible reduction in traffic capacity at roundabouts or signalled intersections due to pedestrians crossing on the surface.

56. It is seldom necessary for pedestrian counts to be continuous throughout the day. Sample counts during peak hours (peak for vehicular traffic or pedestrian traffic or both) and during an average hour will usually suffice. Counting of pedestrians is best done with hand tally counters and flows of up to 2,000 per hour can be counted by one observer. Recording with pencil and note book is satisfactory for flows up to 1,000 per hour. Special forms are hardly necessary for this purpose.

57. If flows of pedestrians crossing are very heavy it may be advisable to take samples to save the strain of continuous counting, e.g. the count may be continued for one minute followed by a one-minute rest and the totals

doubled. Separate observers for each direction will be required.

58. For heavy flows moving along a street the moving observer technique can be used. The observer traverses the street in one direction, counting all the pedestrians he passes, in whichever direction they are moving and deducting all the pedestrians which overtake him. He then re-traverses the street in the opposite direction moving at the same speed and counting as before. The average of the two counts gives an estimate of the total number of pedestrians on one side of the street during the count.

59. Consideration must also be given to the peak-hour discharge of pedestrians from railway, bus and coach stations, industrial estates, stores, offices or commercial buildings which have a particular bearing on the provision and design of pedestrian facilities.

Public Transport

60. For the consideration of many traffic problems it is desirable to know what part public transport plays in the movement of people in an area.

61. Information on public transport should be collected under the following headings:

(i) routes and stopping places

(ii) frequency of service

(iii) passengers carried and - where the passenger demand appears to be in excess of the capacity -

(iv) queues - number of persons waiting and average waiting time.

62. Details of (i) and (ii) may be obtained from the Transport Manager, who may also be ready to give information on the occupancy of vehicles (loading of services) if his interest is enlisted by an explanation of the reasons why the information is required and the purposes for which it will be used.

63. Some measurement of the regularity of service during peak hours, as distinct from the intended frequency, may be necessary. This is often a valuable index of congestion, and may also be obtainable from the Transport Manager, or can be observed at the same time as the study of passengers carried.

64. The number of passengers carried should be observed and recorded at predetermined points where the heaviest loads are known to occur and at other important points including the bus stops nearest to the points where an O & D survey has been carried out. The information from these counts can be related to the known capacity of vehicles and the frequency of service to give standard of service. The observations should cover both peak and average hours and are best made by the Transport Company with their regular personnel, who may in fact already be collecting such information.

65. The information required may be summarised in the following way which will be familiar to the Transport Manager:

Arrival time	PASSENGERS			
	Arrival load	*set down*	*picked up*	*Departure load*

66. In the relatively few cases where the information cannot be obtained through the Transport Manager, it will be necessary to make special studies.

67. The number of passengers on single-deck buses can generally be counted by an observer walking along the pavement whilst the bus is stationary. The procedure varies according to the loading as follows:

light loading:	count passengers
heavy loading:	count empty seats and subtract from the known capacity
loading in excess of capacity:	count number of standing passengers and add to the known capacity

68. For double-deck buses it will be necessary for the observer to travel a short distance on the bus, and for this purpose it will be necessary to make arrangements with the Transport Manager.

69. A note should be made of scheduled stops where passenger demand exceeds capacity and the number of intending passengers waiting.

70. This information will be useful in assessing the density of the passenger traffic at the particular point. The arrival times give the required check on the regularity of service.

71. Measurements of queues should also be made during peak and non-peak hours. The number of people waiting in the queue should be counted at regular intervals, preferably not exceeding 5 minutes, throughout the hour. The total number of people joining the queue during the hour should also be noted (n). The

average waiting time or delay in seconds may then be calculated as:

$$d = \frac{3{,}600 \times p}{n} \text{ seconds}$$

where p is the average number waiting in the queue as given by the periodic counts.

72. In some areas the effect on road traffic of passengers or goods arriving or departing by rail can be significant. The frequency of rail services, the number of passengers or volume of goods carried and the amount of road traffic generated should be measured, particularly at peak hours. This generated road traffic may of course comprise pedestrians, cars, 'buses', or goods vehicles.

Origin and Destination Surveys for Small or Medium Sized Towns

73. Where land use/transport plans have not been formulated and it is necessary to plan for a new road, or extensive alterations to an existing road, the amount of traffic likely to use it cannot be obtained from simple censuses and it is necessary to collect information on the origins and destinations of traffic approaching the survey area. Even where extensive physical improvements are not proposed the preparation of a traffic plan should be based on a knowledge of traffic desires rather than on existing flows which may be influenced by unsatisfactory conditions on certain routes.

74. Generally there are two distinct problems which arise in an urban area and it may or may not be possible to obtain the information for both these problems from the same origin and destination survey. The first problem is that of providing for through traffic, which does not require to call in the urban area, by means of a by-pass or ring road and for this the survey points should be located on the radial roads at points near to where traffic will eventually join the by-pass. The second problem is that of dealing with traffic which has origin or destination inside the town, through traffic which has business in the town and local traffic which circulates entirely within the town, and the survey points will have to be carefully chosen and sited.

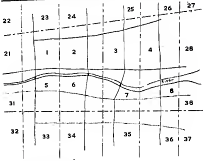
75. In considering a diversion intended to take through traffic away from a particular road, it is simply necessary to classify the traffic as by-passable or non-by-passable. In a scheme to deal with more complicated traffic movements there is likely to be an advantage in dividing the town into a number of zones as illustrated in Fig 8: it is important to select small zones for the survey; they can be amalgamated later if required for the analysis. The survey information would be designed to separate out movements between pairs of zones and between each zone and places outside the urban area. The location of these zones requires considerable local knowledge supplemented by such information as is obtained during the preliminary reconnaissance and discussion with the planning authorities. They should be the same as, or at least fit in with, those likely to be used in conjunction with the land use/transport survey. Generally natural barriers such as rivers and railways should form the boundaries of zones and the zones themselves should be as homogeneous in use and character as possible: the geometric shape is of minor importance.

76. The siting of survey points, particularly if vehicles are to be stopped, requires care. They should preferably be sited on straight level stretches of road with adequate visibility in each direction. The carriageway must be sufficiently wide to avoid creating dangerous conditions and, if sampling is to be used, it must be wide enough to allow vehicles which are not required for questioning to by-pass the survey point. Where two roads meet at a fork it may be more economical to have one survey point located in the common branch, but if conditions are not favourable there will have to be two survey points, one on each approach. The survey points should obviously not be located close to intersections where delays and danger might occur, but exceptionally it is possible to interview a sample of drivers stopped at a red traffic light provided traffic is not delayed when the green period starts.

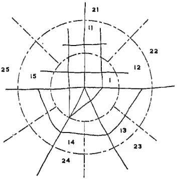
77. There are no statutory powers to stop or slow down vehicles for the purpose of taking a survey. It is essential therefore that the full co-operation of the police should be obtained and a constable should be present at each point whilst the survey is in progress. Whilst the stopping and marshalling of traffic at the survey point is a matter on which the police have control, the correct positioning of the constable on duty is of considerable importance to the smooth running of the survey. Generally the constable should be sited near the first enumerator (i.e. the one most remote along the line in the direction of travel) since, even with adequate signs, many drivers tend to stop close to the policeman instead of at the survey point. If he is too far in advance therefore many drivers will be stopped twice. In a sample survey the constable will select the sample of vehicles for interview but this must be done strictly in accordance with some pre-arranged rule. (See paras 172–178 for sample sizes.)

78. If the survey is continued during hours of darkness sufficient light must be provided to enable the enumerators to record correctly and, if there is not full street lighting, steps must be taken to ensure the safety of

TYPICAL ZONING PATTERNS
FOR O & D SURVEYS



(a) Rectangular pattern zoning

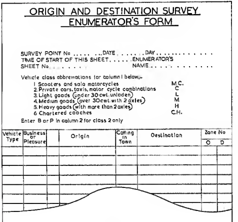


(b) Radial pattern zoning

FIG 8

vehicles and of personnel engaged on the survey. Adequate advance warning signs either reflectorised or illuminated should be provided well in advance of the census point.

79. The duration of an origin and destination survey is generally limited to three days, Friday, Saturday and Sunday or Saturday, Sunday and Monday (16 hours per day) in the case of by-pass schemes. For schemes such as ring roads it may be desirable to replace the Sunday survey by one on another weekday.



ORIGIN AND DESTINATION SURVEY
ENUMERATOR'S FORM

SURVEY POINT No .... DATE .... DAY ....
TIME OF START OF THIS SHEET ..... ENUMERATOR'S
SHEET No .... NAME ....

Vehicle class abbreviations for column 1 below,-

1 Scooters and solo motorcycles	M.C.
2 Private cars, taxis, motor cycle combinations	C
3 Light goods (under 30 cwt unladen)	L
4 Medium goods (over 30cwt with 2 axles)	M
5 Heavy goods (with more than 2 axles)	H
6 Chartered coaches	C.H.

Enter B or P in column 2 for class 2 only

Vehicle Type	Business or Pleasure		Origin	Calling in Town	Destination	Zone No	
						O	D

FIG 9

80. There are five basic methods of carrying out an origin and destination survey, namely:

By direct interview of drivers
By observation of registration numbers
By use of postcards
By tags or stickers on the vehicles
By home interviews or works interviews where appropriate.

81. Combinations of these methods are sometimes used, e.g. stickers may be used in a direct interview survey to avoid drivers being stopped twice. A brief description of these methods follows.

Direct Interview Method

82. In this method drivers (or a sample of drivers) are stopped and questioned as to their origin and destination. Additional questions may be asked depending on the information required, e.g. for a by-pass survey it is necessary to find out whether drivers specially wish to call in the town whilst for a more comprehensive survey drivers with destination in the town must be asked for the street or building so that they can subsequently be allocated to the correct zone. This method gives detailed information provided the questions are carefully framed and kept to a minimum so that the answers obtained are clear and precise and drivers are not unduly delayed.

83. Generally one enumerator is required for 80–100 vehicles per hour. If the volume exceeds 200 vph it may be better to take a sample of drivers rather than increase the number of enumerators. The sampling procedure

must be designed so that no bias is imparted to the results. The following methods can be used:

(i) A fixed fraction of the drivers is questioned, the fraction being chosen in advance, e.g. if the fraction is one-third every third vehicle is stopped and the remaining two are allowed to pass unhindered. The police constable must be given instructions to apply the rule strictly regardless of size or speed of the vehicle. The fraction may be varied at different times of the day, a smaller fraction being interviewed during peak hours. Changes should not be made within an hour but if the enumerators become overloaded the interview should be suspended for a short time and a numerical count of all vehicles substituted. Apart from this possibility numerical counts should not be necessary, the total number being obtained by multiplying the number of vehicles interviewed during a particular hour by the reciprocal of the sampling fraction used during that hour. The fraction should be chosen to give the enumerator up to 80–100 vehicles per hour.

(ii) The enumerator can be allowed to choose the sampling fraction according to his ability to cope with the task. As soon as he has finished with one driver he gives a signal to the policeman who then has instructions to stop the first vehicle to cross a line specially marked on the road. This procedure must again be complied with strictly. Since the fraction of vehicles sampled varies with the flow and with the ability of the enumerator the sampling fraction must be obtained by making a separate classified count of all vehicles passing the survey point. A separate sampling fraction is calculated for each class of vehicle during each hour of the survey.

(iii) At places where vehicles have to stop such as a signalled intersection or level crossing the drivers of stationary vehicles can be questioned. Sufficient enumerators should be employed to question most of the vehicles which are likely to be stopped and an additional man should make a classified count of all vehicles.

84. Questions are best put to drivers by showing them a card on which the questions are printed in bold letters (say ½ inch) with a request that they be answered. Where enumerators are left to ask the questions verbally it is found that, towards the end of the day, distortion of the wording can occur sufficient to mar the results of the survey. The enumerators should be provided with a stiff board on which to rest the forms and a transparent cover for use during wet weather is a useful addition. The design of the form must depend on the questions to be asked and on the type of analysis, manual or punched card. An example of a form used for punched card analysis is shown in Fig 9.

85. The layout of a typical survey point for a sample survey is shown in Fig 10. The enumerator questions on the driver side of the vehicle and is protected from vehicles passing behind him by a row of tar drums or rubber cones. Interview surveys are usually made only on traffic entering the urban area. If a survey of outgoing traffic is required it should either be made on a different day or a site found where the survey points for the two directions can be adequately staggered.

86. Interviewing of drivers is tiring work and generally one man should not be continuously employed on interviewing for more than two hours. It is best to cover the day by means of two teams working alternately in short periods of 1 to 1½ hours throughout the day (the shifts should be chosen so that meal breaks occur at reasonable hours) or by means of a single team covering the two shifts on different days. There must be adequate supervision.

Registration Number Method

87. In this method the registration numbers and class of each vehicle is observed and recorded as it passes each survey point together with the time of passing, usually to the nearest minute. By subsequently comparing the records from all the survey points the points of entry and exit of through vehicles and journey times are obtained. The origins and destinations of the vehicles are taken at the points where they enter and leave the survey area. The limitation of this method is that no information as to the actual origin or destination of local traffic is obtained, such as is necessary for a comprehensive survey. Its main advantage lies in the fact that no vehicles are stopped.

88. Unless traffic is very light (when one man can both observe and record the vehicles passing in one direction) it is usual to employ a pair of men for each direction of travel. One man observes the registration numbers and calls them out to a second man who records them on the field sheet. The first man has a watch and calls out the time at minute intervals which the second man records on his sheet. Two men, in this manner, can record volumes up to about 300 vph. For heavier volumes it is usual to sample the vehicles by recording only registration numbers ending in certain digits. The same sampling procedure must be used at every survey point.

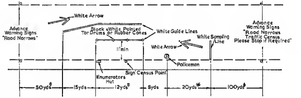
89. Disadvantages of this method are that a large team is required since every survey point must be manned simultaneously, and the analysis is very tedious unless mechanical sorting is used, and errors in field recording

are difficult to avoid and tend to introduce bias in the results.

Postcard Method

90. In this method a prepaid postcard, or business reply card, setting out in tabular form the information required is handed to every driver as he passes the survey point, to be filled in by him and posted at the end of the journey. This is a simple method especially suitable where traffic is heavy and moving slowly so that a card can be handed to the driver as he passes. The success of the method depends on the willingness of drivers to co-operate and correctly answer the questions so that adequate publicity as to the object of the survey is essential. Since it is not practicable to follow up non-replies there is considerable danger of bias being introduced unless a very substantial proportion of the cards is returned. As it cannot be predicted beforehand how good the response will be the method involves some risk.

ORIGIN AND DESTINATION SURVEYS
TYPICAL LAYOUT OF CENSUS POINT
TWO WAY ROAD


White Arrow
Advance Warning Signs "Road Narrows"
Block & White Painted Tar Drums or Rubber Cones
White Guide Lines
White Sampling Line
Advance Warning Signs "Road Narrows Traffic Census Please Stop if Required"
11' min
White Arrow
Policeman
Sign "Census Point"
Enumerators Hut
50yds ɸ
15yds
12yds ‡
5yds
20yds ✱
100yds ɸ

NOTES

1 This arrangement is for use with sampling by the "next come, next questioned" method. For "fixed fraction" sampling the dimension marked ‡ should be (4+8n) yds where n = the maximum number of enumerators.

2 For Unrestricted Roads the distances marked ɸ should be increased to be of the order of 250yds if practicable, the distances marked ✱ should be increased and the advance signs must be preceded by signs "SLOW—TRAFFIC CENSUS AHEAD" in 6" and 4" letters.

FIG 10

Tag Method

91. With the tag method drivers must be stopped twice if the maximum amount of information is to be obtained and for this reason careful consideration is required before using it. The usual procedure is to stick a tag of distinctive colour and shape on the windscreen of each vehicle at the incoming point, a different colour and shape being used for each survey point. At the same time the driver is handed a card bearing the point number on which the enumerator writes the time of entry. At the outgoing end the driver surrenders the card and enumerator records on it the time of exit and the outgoing survey point number. The method gives little more information than the registration number method except that by having enumerators stationed at intermediate points, who record the point of origin from the colour and shape of the tag, it is possible to trace the routes through the town used by vehicles. These intermediate enumerators do not stop the vehicles.

Home Interview Method

92. This method is not likely to be used except in those areas where comprehensive land use/transport surveys are being done. A sample of the population is questioned at home by trained personnel with the object of discovering all the journeys made on the previous day or days; at the same time it is usual to collect other information from each household sufficient to enable forecasts to be made of future travel movements in the

area. This information, supplemented by direct interviews at an external cordon on the periphery of the survey area, and by the collection of information from the operators of goods vehicles, public transport and taxis, can give a comprehensive picture of the traffic circulating within the survey area. Advice on these surveys is to be issued.

Speed Measurements (Including delays and flows)

93. The methods of measuring the speed of vehicles falls broadly into three groups:

(1) **Spot Speeds** – the instantaneous speeds of vehicles at particular points.

(2) **Running Speeds** – the average speeds of vehicles along sections of road excluding delays at controlled intersections.

(3) **Journey Speeds** – the average speed of vehicles along a route including all delays (other than voluntary stops).

94. Spot speeds are required when considering changes in speed limits – the percentages of vehicles travelling at various speeds are then needed. They are sometimes required for siting detectors for traffic signals and may also be used for an approximate estimate of journey speeds.

95. Running speeds are useful for measuring traffic capacity of streets.

96. Journey speeds are of wide application in urban areas and may be used for:

(i) Measuring the adequacy of an existing road network.

(ii) Assigning traffic to appropriate routes (O & D surveys).

(iii) Economic assessments.

(iv) Measuring the success of improvement measures ('before' and 'after' studies).

Measuring Spot Speeds

General

97. When a large number of spot speed observations is taken the most common speed is usually about equal to the average speed, i.e. the arithmetic mean of all the speeds.

98. The speed exceeded by 15% of the vehicles (85 percentile speed) is generally about 1·20 times the mean speed and the speed exceeded by 5% of the vehicles (95 percentile speed) is about 1·32 times the mean speed.

99. The mean speed can be estimated from that of a sample of vehicles and it is important to avoid bias in selecting the sample. Bias can be avoided by choosing a sample consisting of every 'n'th vehicle passing a particular point. A sample of 100 vehicles is usually regarded as adequate for spot speed measurements.

Radar Speedmeter

100. A direct reading of speed can be made with a radar speedmeter. This instrument employs a radar transmitter which beams high frequency radio waves on to the vehicles. The waves reflected back from moving vehicles have a different frequency to the transmitted waves, the difference between the two frequencies being proportional to the speed of the vehicles. The difference is indicated on a meter calibrated in mph. The speeds of both approaching and receding vehicles can be measured.

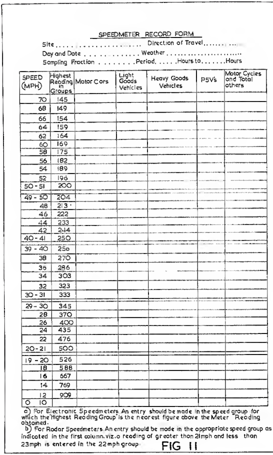
101. The instrument is portable and set up by the side of the road when required although care must be taken to align the instrument correctly with respect to the line of travel of vehicles. It is powered by a car type accumulator. A form similar to that shown in Fig 11 (but disregarding the second column) may be used to record the results.

Electronic Speedmeter

102. An electronic speedmeter is available which measures accurately the time taken for vehicles to pass between two detectors laid across the road approximately 6 ft apart. (The exact spacing is 70·4 ins and it is important the detectors should be accurately laid and, if of the rubber tube type, of equal length.) By means of a hand switch the instrument can be held inoperative until the moment decided by the operator. In this way an individual vehicle can be picked out for measurement from a heavy stream of traffic. After measurement of the speed of this vehicle the instrument is automatically made inoperative until reset by the operator. The result of a measurement is displayed as a 3-digit number which can be converted to mph by reference to a table. Use of the form shown in Fig 11 enables the conversion to be made immediately and also presents the measurements in a form suitable for subsequent analysis.

Observation Method

103. On a section of road where two observers can see one another the time taken for vehicles to traverse a measured distance can be timed usually on a stop watch.



SPEEDMETER RECORD FORM

Site . . . . Direction of Travel. . . . .
Day and Date . . . . Weather . . . .
Sampling Fraction . . . . .Period. . . . . .Hours to. . . . . . .Hours

SPEED (MPH)	Highest Reading in Groups	Motor Cars	Light Goods Vehicles	Heavy Goods Vehicles	PSV's	Motor Cycles and Total others
70	145					
68	149					
66	154					
64	159					
62	164					
60	169					
58	175					
56	182					
54	189					
52	196					
50 - 51	200					
49 - 50	204					
48	213					
46	222					
44	233					
42	244					
40 - 41	250					
39 - 40	250					
38	270					
36	286					
34	303					
32	323					
30 - 31	333					
29 - 30	345					
28	370					
26	400					
24	435					
22	476					
20 - 21	500					
19 - 20	526					
18	588					
16	667					
14	769					
12	909					
0 10						

a) For Electronic Speedmeters An entry should be made in the speed group for which the "Highest Reading Group" is the nearest figure above the Meter Reading obtained.

b) For Radar Speedmeters An entry should be made in the appropriate speed group as indicated in the first column. viz. a reading of greater than 21mph and less than 23mph is entered in the 22mph group.

FIG 11

Two observers are normally employed one starting and stopping the watch as the vehicle enters and leaves the section and the second observer signalling from the end of the section remote from the first observer.

104. A convenient distance is 147 ft when the speed in mph is given by $\frac{100}{t}$ where t is the time in seconds to travel 147 ft. Any multiple of 147 ft can be used with corresponding adjustment of the formula.

105. Alternatively it may be possible for one observer to be positioned (e.g. from an upper window of a building) so that he sees both timing points.

Enoscope Method

106. Measurements can also be made by a single observer using an instrument known as an Enoscope which by a system of mirrors enables him to judge accurately the passage of the vehicle past the distant end of the section.

By Cine films

107. Speeds of vehicles have on occasions been measured by taking cine films records and measuring the movement between successive frames. This method has disadvantages due to frame speed variations, variations in distance of vehicles from the camera, difficulties of siting the camera and so on which make it of restricted use.

Measuring Running Speeds, Journey Speeds, and Flows

General

108. Journey and running time measurements should be taken for both peak and normal conditions and the results tabulated ready for conversion to speeds (see para 179).

Moving Car Method

109. In urban areas information on flows, speed running and journey times can be obtained conveniently by observers in moving cars. The cars each containing three observers and the driver are driven to and fro along the route. One observer counts the vehicles passing in the opposite direction, the second observer counts the number of vehicles overtaking the test car and also the number of vehicles which the test car itself overtakes whilst the third observer records times and the totals counted by the other two observers.

110. The limits of the sections on which the counts are recorded are usually chosen at the major intersections along the route. Delays at intersections are recorded as the vehicle travels along. It is usually found that a dozen or so runs at the appropriate times of the day spread over several days give reasonably consistent results.

If q is the average number of vehicles passing through the section in unit time in one direction
x is the average number of vehicles counted in this direction when the test car is travelling in the opposite direction
y is the average number of overtaking vehicles less the number overtaken when the test car is travelling in the direction of q
w is the average journey time taken by the test car to travel over the section in the direction of q
a is the average time taken in the opposite direction, this is given by

the average flow $q=\frac{x+y}{a+w}$

and the average journey time t of the stream q is given by

$$t=w-\frac{y}{q}$$

111. To obtain the average journey speed the length of each section should be divided by the average journey time. (See J.G. Wardrop and G. Charlesworth 'A method of estimating speed and flow of traffic from a moving vehicle' – Journal I.C.E. Pt II Vol 3, February 1954.)

112. If the average running time of the stream is required it can be obtained by subtracting the average total delay in the section in the appropriate direction from the average journey time. From this the average running speed can be obtained.

113. The moving car method is of particular value for surveys of existing conditions in urban areas as it supplies information on traffic volumes in each direction of travel, delays at road junctions as well as journey times and speeds, but cannot of course give flows in one-way streets which must be dealt with independently.

114. A simpler variant of the moving car method is by driving the test vehicle so that the number of vehicles overtaken is the same as the number of overtaking vehicles. The test vehicle is then travelling at the mean speed of traffic.

Registration Number Method (for journey times)

115. Two observers with synchronised watches are stationed at each end of the section (of known length) and record the registration numbers of vehicles and the times at which they passed. If traffic is heavy it is sampled by recording only numbers ending in certain digits.

116. By matching the records of the two observers the times taken by vehicles to pass through the section can be determined. In practice little difficulty will be experienced in rejecting the journey times of those vehicles which stop in the section.

Delays

117. In certain areas the delays at intersections are of interest. Delays can be measured directly by making a number of test runs through the intersection, an observer in the car noting the times with the aid of a stop watch, and recording when he has an unhindered passage through the intersection. The average delay is therefore the difference between the mean journey time of all runs and the mean time of unhindered runs. If there are very few unhindered runs the average 'unhindered' journey time may be estimated using an assumed speed.

118. If there is a reasonable vantage point near the intersection, observations of delay may sometimes be carried out more conveniently with an observer noting the time a vehicle passes a fixed 'entry point',* and the time it leaves the intersection, denoting unhindered runs as before. When an observer has timed a vehicle out he should straightaway take the next vehicle to pass 'in point'. If a mean delay is found from these results there will be a bias underestimating the delay since, a larger sample of runs will be taken during times of low flow when delays are generally lower. The bias can, however, be practically eliminated if the main delay of runs in a short period of, say, 5 minutes is multiplied by the flow in that period and the weighted mean delay for a much longer period found.

119. Alternatively the accumulation of cars in the queue waiting to clear the intersection can be noted. If the number of cars in the queue is plotted against time, the area under the graph gives the total vehicle delay in that time. Knowing the number of vehicles arriving the average delay per vehicle can then be calculated. To save drawing a graph and measuring the area the following approximate method can be used:

120. Over a period of one hour, the number of vehicles at rest or virtually at rest in the queue is noted at minute intervals. The average of the 60 counts is then calculated. The average delay in seconds is given by

$$d = \frac{3{,}600 \times \text{average number of vehicles in queue}}{\text{traffic entering (in vph)}}$$

121. A different interval from a minute should be used if this happens to coincide with the cycle time of the traffic signals.

122. Delays should be obtained for both peak hour and average conditions.

123. The average delay to pedestrians in waiting to cross the road can be found in the same way. The total number n of pedestrians crossing the road is counted and during the same hour an instantaneous count is made at one-minute intervals of those waiting to cross. If p is the average of the one-minute counts then the average delay is given by

$$d = \frac{3{,}600 \times p}{n} \text{ seconds}$$

Accident Studies

124. A systematic study of road accidents is required to measure the safety standard of the existing street network and to pinpoint black spots which may require early treatment. The information on accidents will be obtained from the police. Where a system of recording similar to that described in Ministry of Transport Circular No. 734 (see para 16) is not in operation a record of accidents preferably covering a period of not less than three years on the more important streets in the town should be obtained. These accidents should be plotted, street by street, on key maps showing the more important road features such as junctions (with form of control), pedestrian crossings, bus stops and so on. A suggested system of plotting which will simplify subsequent analysis is given in paras 180–190.

Parking Surveys†

125. Although congestion may be known to exist in certain streets information is often lacking as to the extent to which parked vehicles contribute to this congestion and of the probable effects of measures which

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* The entry point should be chosen at a distance from the intersection far enough to include most likely queues. If a queue happens to extend beyond the 'entry point', the end of the queue should for the time being be taken as the 'entry point'.

† The recent publication Parking in Town Centres (Planning Bulletin No. 7 issued by Her Majesty's Stationery Office 1965) sets out comprehensively the principles for formulating a parking policy and describes comparable methods of carrying out parking surveys framed particularly to facilitate the preparation of a town centre parking map.

may be considered to restrict or prohibit waiting. The information required may be obtained by means of a parking survey.

126. Parking surveys should normally be carried out on the day of the week when the usage is greatest: exceptional peak periods which might occur only a few days a year should, however, be avoided. A further count on an average day would be necessary when an estimate is to be made of the financial return from providing a car park. The early autumn is usually the best time of the year for these surveys.

127. If it is desired to separate the classes of parked vehicles, e.g. (a) shopping, (b) commercial and (c) residential – particularly where it is likely that redevelopment will cater for some of the classes – this may be done by direct interviews. A rough estimate can be made by taking counts at different times: for example a count on early closing day would give (b) and (c), a count on a Saturday afternoon would usually give (a) and (c) and a count after 6 pm would give (c) only. The estimates are made of each class either directly from the surveys or by comparison between them.

128. The information derived from parking studies and interviews for the purpose of determining the amount of off-street parking space required needs to be used with caution bearing in mind that future parking may have to be paid for and that redevelopment of the area will alter demands. Questions as to whether the driver would pay for parking and how much are very relevant as it may be found that a large proportion of drivers will either seek free accommodation more distant from their areas of business or may in fact prefer to use public transport.

129. A parking survey usually comprises three separate studies as follows:

(a) a study of the existing facilities for parking both on and off the street,

(b) a study of parking usage,

(c) a study of parking duration.

130. These studies are usually confined to the central area of a town but may need to be extended to zones bordering this area.

Inventory of Parking Space

131. The inventory of the existing facilities for parking should be broken down into the following categories:

(i) Kerbside spaces,
  (a) officially authorised street parking places,
  (b) officially authorised meter parking places,
  (c) streets not subject to restrictions on waiting,
  (d) streets subject to waiting restrictions.

132. Except where angle parking is allowed, a length of 20 ft of kerb should be assumed for each parking space, care being taken to exclude vehicular entrances to buildings, bus stops and other places where vehicles should not wait.

(ii) Off-street spaces,
  (a) available to the general public: open air sites; garages.
  (b) private parking within building curtilages.

133. Information collected should include the location of each site, the number of spaces available and the charge (if any) made. The information obtained in this study is usually plotted on a 1:1,250 map of the area.

Parking Usage Study

134. A study of the number of vehicles actually parked in a given area, usually referred to as a parking usage study, will not necessarily give a true picture either of the total demand for parking in the area or of the distribution of that demand throughout the area. The distribution of demand will be affected by the difficulty which drivers find in parking in certain streets where the parking is at or near saturation point causing them to park in less suitable streets. The potential demand for parking can be much higher than the actual usage if the available space is so limited as to cause drivers to park outside the area or to refrain from making journeys by private transport. Estimates of the distribution of demand can be made by questioning drivers as they park the cars but estimates of the potential demand can only be obtained from more elaborate surveys which include questioning of the occupants of premises and shoppers in the area or from Home Interview and Cordon surveys. In the absence of such information, a count of vehicles actually parked showing the extent to which individual streets and off-street facilities are used in relation to their capacity does provide a rough indication of the relative demand in different areas.

135. The counting of parked vehicles is usually done at ½-hourly intervals for on-street parking and hourly intervals for off-street parking from 8 am to 6 pm (or such other hours as may be appropriate in a particular town) by teams consisting of a driver and one or two observers in a car which travels over selected routes in the area. The routes should be selected so that all the streets in the area can be included either on one day or spread over several days according to the manpower available.

136. In some large towns the number of vehicles parked has been counted from aerial photographs taken at appropriate intervals.

Parking Duration Study

137. If all the vehicles entering and leaving an area were to be observed continuously it would be possible to determine the exact length of time for which each individual vehicle parked. Such a study is generally impossible on the score of cost. Instead the usual practice is for observers to cover a number of streets at regular intervals throughout the period 8 am to 6 pm (or other appropriate period) and note the registration numbers (the letters can generally be ignored) of all vehicles parked. The interval chosen is a compromise between the desire to obtain detailed and accurate information, and the need to keep manpower requirements to a minimum. Intervals longer than half an hour are not generally accurate enough for street parking and in shopping streets a shorter interval (10 minutes to a quarter of an hour) is often necessary. For off-street facilities, where the proportion of drivers parking for less than one hour is usually very low, an interval of one hour will suffice. Where a parking duration study is made a separate survey for parking usage studies is not required.

138. The duration of parking is estimated from the number of occasions on which a given vehicle is seen. If the interval is half an hour it is assumed that a vehicle which is seen once has parked for half an hour (the duration could be from 1 to 59 minutes). A vehicle seen twice is assumed to park for one hour and so on.

PART 3

Analysis and Presentation of the Results of Survey and of Accident Data

Introduction

139. Part 3 deals with the processing and presentation of the data collected in accordance with the recommendations made in Part 2. This stage can be much lightened by careful attention to the field work. The standard forms suggested in Part 2 make for accurate recording; and they present the basic information in a form suitable for processing. It is, however, essential before data is collected that sufficient thought be given to the use to which it is to be put. This part should therefore be read in conjunction with Part 2 before starting field work. It is also very important that suitable grades of labour are used (office staff accustomed to figure work are best).

140. The main purpose of this stage is to condense the data into a form in which the salient features of the problem can be recognised and which can be used to trace the possible consequences of the various solutions which may be proposed as a result. The first stage in the presentation usually consists of a description of the methods employed in collecting the data and of the various results which emerge. An Appendix should include detailed tables and diagrams in a form suitable for subsequent analysis of schemes. The preparation of the final report, in which presentation is of the utmost importance in securing administrative and financial agreement to the proposals, should be borne in mind at this stage.

Traffic Censuses

141. Much of the traffic census information referred to in Part 2 is required as background data in the general preparation of the results. It is useful, however, to present some of it in the form of graphs and diagrams. For example, the annual growth of peak hour traffic can be plotted for different areas for forecasting future traffic as in Fig 12.

142. Seasonal variations in flow can be plotted and by marking reciprocal values to the flow at peak season, estimates can be readily made from flows taken at other times of the year, of the peak season flows as in Fig 13.

143. The variations in daily flow may be plotted as in Fig 14.

144. As peak-hour flows determine the capacity required both for roads and at junctions graphs such as shown in Fig 15 (for each direction of traffic) are useful in

ANNUAL GROWTH OF PEAK HOUR TRAFFIC

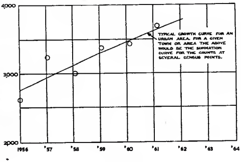


FIG 12

SEASONAL VARIATIONS IN TRAFFIC FLOW

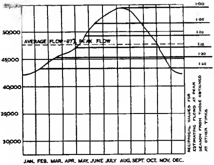


FIG 13

THE ABOVE DIAGRAMS ILLUSTRATE METHODS OF PRESENTATION ONLY AND SHOULD NOT BE ASSUMED TO APPLY TO INDIVIDUAL TOWNS.

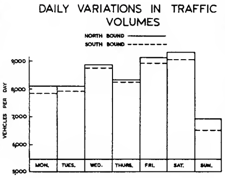

DAILY VARIATIONS IN TRAFFIC VOLUMES
NORTH BOUND
SOUTH BOUND
VEHICLES PER DAY
9,000
8,000
7,000
6,000
5,000
MON.
TUES.
WED.
THURS.
FRI.
SAT.
SUN.

FIG 14

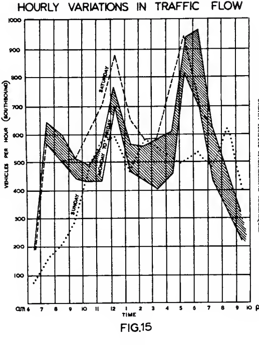

HOURLY VARIATIONS IN TRAFFIC FLOW
VEHICLES PER HOUR (SOUTHBOUND)
1000
900
800
700
600
500
400
300
200
100
SATURDAY
MONDAY TO FRIDAY
SUNDAY
am 6
7
8
9
10
11
12
1
2
3
4
5
6
7
8
9
10 pm
TIME

FIG.15

showing when the peak flows occur and the relationship of peak flows to flows at other times of the day and on different days of the week. It is usually found that the pattern of traffic on week-days Monday to Friday is similar, and can be covered by a band (as shown hatched). These diagrams can also be useful in deciding at what times restrictions on waiting, etc., should be applied.

145. The results of a distribution census at an intersection are summarised on the forms shown in Figs 6 and 7. A useful method of presenting these results is in the form of the diagram shown in Fig 16, in which the widths of the various bands are proportional to volumes of traffic in each stream. A scale of 50 vehicles per hour per ft of carriageway width gives a rough indication of entries or exits which are near to capacity. These diagrams may be drawn for the average hour and for peak hours. Where a number of intersections are closely associated it may be an advantage to include them all on the same diagram.

PRESENTATION OF DISTRIBUTION CENSUS

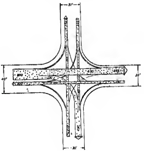


FIG 16

146. It is particularly convenient for rapid reference to note on a map of, say, $\frac{1}{2,500}$ scale the morning and evening peak flows in each direction of travel and similarly to indicate the major turning movements at road junctions. For convention see Fig 53. This diagram illustrates also a convenient method of setting out traffic data at a junction.

147. When a roundabout is proposed for an intersection, the data must be analysed to give the volumes on each side of the roundabout: Fig 44 shows a convenient method of making the necessary calculations. The results may be illustrated as in Fig 17.

PRESENTATION OF ROUNDABOUT ANALYSIS

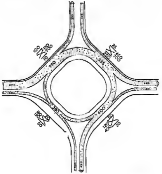


FIG 17

148. Pedestrian counts are generally included as numbers on a traffic diagram with arrows across the carriageway to show the points at which the counts were made.

Public Transport

149. The information on public transport is generally best summarised street by street in the form of a table under the headings (i) to (iv) given in para 61. Where appropriate some of this information can also be shown on a map of the town giving the routes and stopping places, and number of public service vehicles per day on each road.

Origin and Destination Surveys

150. The greatest amount of analysis will generally be required for the origin and destination survey, and it is here that perhaps the greatest savings can be made by careful planning of the field work suitable for processing and analysing at a later stage.

151. For the simpler types of survey where all that is needed is the traffic volumes likely to use a new or improved route, it is convenient to include on the enumerator's form extra columns on the right hand side so that each entry can be subsequently coded as to whether or not the vehicle would have used a diversion. Generally this may be done by inspection of the answers given to the questions, but if the diversion is considerably longer than the route through the town it may be necessary to make comparison of journey times for typical journeys taken via the old route and estimates of journey times via the diversion.

152. The exact procedure to be followed in analysing a by-pass survey depends upon the lines which have been proposed for the diversion but the following simple example illustrates the method. Fig 18 shows in diagrammatic form alternative lines for a north/south by-pass to a small town; the same principles would apply to a relief road or by-pass to a town or district centre. The problem here may be that whilst the construction of a by-pass to the west would present fewer engineering difficulties than one to the east, the latter would afford better traffic facilities by taking some of the east/north and east/south traffic from the town. It may thus be desired to determine whether the value of these additional facilities justifies the extra cost of constructing the by-pass to the east. Fig 19 shows the enumerators sheet which might be used for such a survey relating to survey point No. 1, and illustrates how each entry may be classified from the field information recorded. Fig 20 is an hourly summary form which follows directly from the right hand columns of Fig 19. Fig 21 is a daily summary form suitable for use either when the survey is taken for a full week (top part of form) or for three days only (bottom part of form). In either case the aim

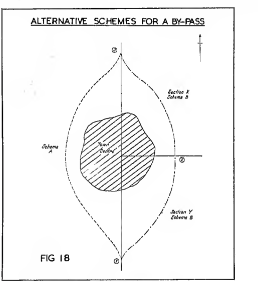
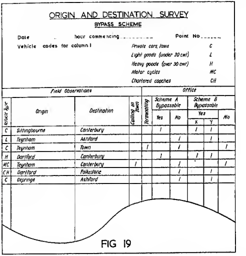


FIG 18

is to produce the daily average (average of seven days) since the design of a by-pass will usually be based on the rural road standards of memorandum No. 780. If the survey has been taken for less than 16 hours per day the results of this analysis will need to be scaled up by a factor obtained from hourly traffic counts taken over the full 16-hour period. When sampling has been employed the results will need further scaling up for each class of vehicle by the reciprocal of the sampling fraction. The sampling fraction may be a theoretical one, e.g. if one vehicle in three is sampled the sampling fraction would be $\frac{1}{3}$ and the results would be scaled up by a factor of 3, or if a complete count has been made the actual sampling fraction, namely,

$$\frac{\text{number of vehicles of given class interviewed}}{\text{number counted}}$$

would be used. The scaling up should be done for each day (for more complicated surveys it may be necessary to do it for each hour's results).



ORIGIN AND DESTINATION SURVEY

BYPASS SCHEME

Date _ hour commencing .... Point No ......

Vehicle codes for column I

Private cars, taxis	C
Light goods (under 30 cwt)	L
Heavy goods (over 30 cwt)	H
Motor cycles	MC
Chartered coaches	CH

Field Observations				Office					
Vehicle type	Origin	Destination	Calling in town	Terminating	Scheme A Bypassable		Scheme B Bypassable		
					Yes	No	Yes		No
							X	Y	
C	Sittingbourne	Canterbury			/		/	/	
L	Teynham	Ashford				/		/	
C	Teynham	Town		/		/			/
H	Dartford	Canterbury			/		/	/	
MC	Teynham	Canterbury	/			/			/
CH	Dartford	Folkestone				/		/	
C	Ospringe	Ashford				/		/	

FIG 19

153. In a simple case such as that illustrated the results may be presented on a diagram such as that shown in Fig 22, but where a larger number of survey points has been used it is best to prepare first a summary table such as that shown in Fig 23 for each category of traffic, namely by-passable, though not by-passable, and terminating. Where alternative by-pass schemes are being considered separate sets of tables and diagrams will be needed for each alternative. In Fig 22 the traffic streams may be shown in distinctive colours one for each survey point and the widths of the bands should be made proportional to the volumes in each stream. It is desirable also to indicate the volume by number as well as by the width of band and estimates of future volumes can be included.

154. If punched card accounting machines are readily available consideration can be given to their use but, as some of the work must in any case be done manually, the use of these machines may not be justified for small surveys. For the survey dealt with above the following particulars could be punched on a card in respect of each incoming vehicle interviewed.

(i) number of survey point incoming

(ii) hourly period (1 to 16 or 1 to 12 according to the duration of the survey)

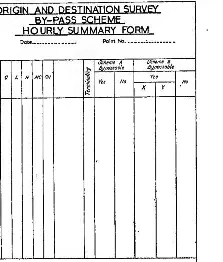
(iii) day of week (coded 1 to 7 or 1 to 3)

(iv) class of traffic, i.e. private cars, goods, etc. (coded according to the number of subdivisions)
(v) scaling factor (reciprocal of sampling fraction)
(vi) outgoing survey point (the terminating traffic can be given a number in this same column)
(vii) whether calling or not in the town (coded 1 for calling and 2 for not calling).

155. The analysis described earlier can then be carried out by mechanical sorting and counting.

(ii) The information for each entry is transferred by lead pencil on to a special card (mark sensing card) and the codes of the origin and destination are added at the same time. The cards are then put through a machine which senses the marks in each column of the card and punches automatically a hole at the same place.

The input to an electronic computer may be paper or magnetic tape instead of punched cards.



ORIGIN AND DESTINATION SURVEY
BY-PASS SCHEME
HOURLY SUMMARY FORM

Date............... Point No...............

Hour	C	L	H	MC	ΠH		Terminating	Scheme A Bypassable		Scheme B Bypassable		
								Yes	No	Yes		No
										X	Y	
6am – 7am												
7 – 8												
8 – 9												
9 – 10												
10 – 11												
11 – 12												
12 – 1pm												
1 – 2												
2 – 3												
3 – 4												
4 – 5												
5 – 6												
6 – 7												
7 – 8												
8 – 9												
9 – 10pm												

FIG 20

156. For the more comprehensive surveys machine analysis is generally justified and on large schemes electronic computers are advantageous. If machines are to be used it is essential to consult the person in charge of the machine work early so that the field sheets can be correctly designed. There are two ways in which the information obtained on the field sheets may be transferred on to punched cards, namely:

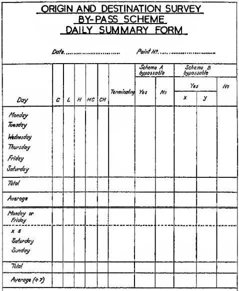
(i) The origins and destinations of each entry are coded manually on the field sheets and an operator is then employed to punch the information relating to each entry on to a card.

157. The procedure for dividing the town into zones has been described in para 75. The numbering of the zones should be done with punched card operation in mind (e.g. if there are more than 10 zones each should be given a two-digit number). Some of the basic information such as the day of the week and number of incoming survey points may be gang punched automatically on to a batch of cards.

158. The basic aim of the analysis should be to produce the volume of traffic between each pair of zones. This information, which is the basic data required for subse-

quent analysis, should be recorded on tables similar to that shown in Fig 23 with zone numbers in place of the survey point numbers. The data may be illustrated by means of 'desire line' charts. Each important stream of traffic is shown by a band whose width is proportional to the volume. This may be done on an outline map of the town on which the various zones are marked or in purely schematic form as illustrated in Fig 24.

The journey time for each vehicle in the n(n–1) through streams is obtained by subtracting the time at the incoming point from the corresponding time at the outgoing point. Each of these through streams is then further analysed into stopping and non-stop categories, the latter being regarded as by-passable. Vehicles are classified as non-stop if the journey time does not exceed a given figure for the particular stream. This figure may be estimated by making trial runs between each pair of survey points. An allowance must be made for slower moving vehicles. The figure can also be decided by statistical analysis of the results. The frequency of occurrence of journeys of various times for a given through stream is tabulated in 1 minute increments. If these frequencies are plotted against the corresponding journey times it may be found that a double hump distribution is obtained. It is generally



ORIGIN AND DESTINATION SURVEY
BY-PASS SCHEME
DAILY SUMMARY FORM

Date.......................... Point No...........................

Day	C	L	H	MC	CH	Terminating	Scheme A bypassable		Scheme B bypassable		
							Yes	No	Yes		No
									x	y	
Monday Tuesday Wednesday Thursday Friday Saturday											
Total											
Average											
Monday or Friday											
x 5 Saturday Sunday											
Total											
Average (÷ 7)											

FIG 21

159. The analysis of a registration number survey consists of matching the recorded numbers and allotting the pairs to their appropriate streams. If there are n survey points there will be

n(n–1) through streams
n shuttle streams, i.e. vehicles entering and leaving at the same point
n terminating streams } Corresponding to the
n originating streams } unmatched entries

possible to fix by eye from this distribution a journey time which obviously includes the majority of non-stop vehicles.

160. The matching of the registration numbers may be performed manually by transferring the information on the field sheets on to a set of 1,000 numbered index cards. The entry for a given vehicle is made on the index card whose number corresponds with the numerical part of the registration number (or the last three digits if there are more than three figures). The number of entries on these cards will be sufficiently small for matching to be carried out. In addition to the registration number, the survey point number and the time of observation are entered on the cards, incoming vehicles being entered on the left-hand side and outgoing vehicles on the right-hand side. To avoid confusion it is preferable to allot odd numbers to the incoming survey points and even numbers to the outgoing points, i.e. point 1 could be an incoming survey point and point 2 the same survey point but in the outgoing direction. Care must be taken that when a vehicle makes more than one journey through the survey area, the matching is done in the correct chronological order, which may be different from the order of abstraction from the sheets.

161. When the various streams have been separated out in this manner the analysis may proceed as described above for the direct interview survey.

162. The analysis of a registration number survey may also be done with punched card machines. For each entry on the field sheets a card is provided with the following particulars:

(i) number of field sheet (for reference purposes)
(ii) number of survey point
(iii) registration number
(iv) whether vehicle seen incoming or outgoing (code number 1 or 2)
(v) class of vehicle (private car, goods, etc.)
(vi) time of passing (two columns for the hour and two columns for the number of minutes past the hour).

163. Some machines are not adapted to subtract hours and minutes to obtain the journey times and it is then necessary to code the time. For such machines the time may be coded into £ s. d., each minute being coded as 4d. This may be done in the process of transferring the data from the field sheets to the cards or it may be performed mechanically as follows:

164. After the preliminary punching the cards are collected together and sorted into 60 piles according to the number of minutes past the hour. Each pile is then fed into a gang punching machine which automatically punches each card with the same code, e.g. all the cards with times of 5 minutes past the hour are punched with the code 1s. 8d.

165. After completion of punching the cards are sorted on the registration numbers and eventually matched. The unmatched entries are tabulated in two ways:

(a) in alphabetical order of the registration numbers
(b) in numerical order of the registration numbers.

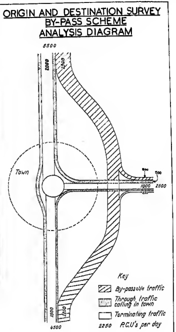
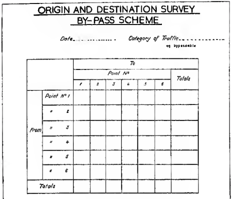


FIG 22



ORIGIN AND DESTINATION SURVEY
BY-PASS SCHEME

Date..................... *Category of Traffic*.....................
eg bypassable

		To						
		Point No						Totals
		1	2	3	4	5	6	
From	Point No 1							
	" 2							
	" 3							
	" 4							
	" 5							
	" 6							
Totals								

FIG 23

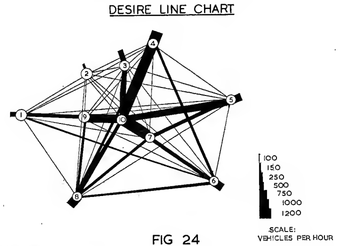


FIG 24

166. Each of these tabulations must be examined manually to detect any matchings which may have been missed due to inaccuracies in the field work. For example, on the alphabetical tabulation two entries might be ABC 459 and ABC 495. If the times are consistent these entries will probably refer to the same vehicle, a transposition of the numbers having been made by one enumerator. Similarly on the numerical tabulation two entries such as ABC 123 and ABG 123 will probably refer to the same vehicle. The residual unmatched entries will be classed as terminating or originating traffic. The matched cards for a given through stream are again fed into the machine which subtracts the incoming times from the outgoing times and prints the results as a frequency distribution of journey times. If the times have been coded this frequency distribution will also be in code and will have to be decoded manually.

167. This analysis of the O and D survey will give an estimate of the volumes and directions of existing road traffic movements.

168. To forecast future traffic these volumes should be scaled up to take account of the growth of traffic arising from increased vehicle ownership – see paragraphs 21, 141 and 142. Account should be taken of the different growth rates in different areas of a town arising from variations in car ownership with income group, and where areas are being redeveloped allowances should be made to cover the traffic generated by the redevelopment.

169. The resultant traffic flows and distribution will require to be allocated to the proposed new or improved road system and one of the accepted ways of doing this is by the 'quickest route' method. By this method traffic assignment is carried out by allocating to the new or improved routes those journeys which show a saving in time if they are transferred thereto. Correction should then be made to the journey times to allow for changes in traffic volumes and the whole process repeated until a reasonably stable position is reached. Although this method is not quite accurate where differences in journey times between alternative routes is small it is sufficiently accurate for most practical purposes. Computer programmes are available for traffic assignment.

170. The estimate of road traffic which results does not of course take into account any changes in the use of public transport other than would occur from the normal increase in vehicle ownership.

171. The conclusions reached from an origin and destination survey, if followed by a comprehensive land use/transport survey, may need to be reviewed when the results of the latter are analysed and policies decided. There will then be a need to look again at particular road schemes already formulated to see whether modifications should be incorporated to bring them into line with plans being formulated for the whole urban area.

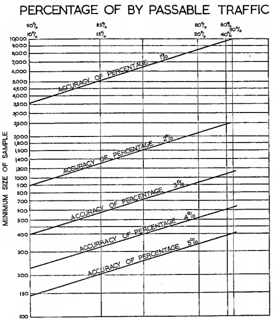
Sampling for O and D Surveys

172. In paragraph 83 methods have been described for obtaining samples of traffic by questioning either a fixed fraction of the drivers, or a variable fraction depending upon the ability of the questioners to cope with the task. In either case it will be necessary to be satisfied that the sample size is sufficient for the results of the survey to be regarded with adequate confidence.

173. In the case of a simple by-pass the problem is usually to assess the volume of traffic which will use the by-pass with a given degree of accuracy. If the proportion of vehicles using the by-pass is p and a sample of n vehicles is interviewed then the estimate of the proportion of traffic using the by-pass obtained from the sample will lie between $p-2\sqrt{\frac{p(1-p)}{n}}$ and $p+2\sqrt{\frac{p(1-p)}{n}}$ on 95% of occasions. These limits are likely to be realistic for the time of year when the survey was made; the difference between the estimate of p and the average value throughout the year is likely to be appreciably greater than these limits suggest, unless seasonal variations are very small.

174. Values of sample size that reduce the calculated limits to stated values are given in Fig 25. It is important to note that the accuracy given in the figure is the actual accuracy of the percentage, e.g. if p is equal to 20% the estimate of p will lie between 19% and 21% if the 1% line is used. The proportional error in the estimate of p, which is the same as the proportional error in the estimate of the flow of traffic on the by-pass, is, of course, greater than this (by a factor 1/p).

175. In most cases it will be found that one questioner, who can cope with 80 vehicles per hour, will be sufficient to obtain an adequate sample in a single day. It is, however, desirable that the survey should be spread over several days if possible, even if it refers only to a particular day of the week, to avoid additional errors due to variations from day to day. In the case of a survey covering 3 days (Friday, Saturday, Sunday) one enumerator will be sufficient. If the survey is only of traffic in peak hours, or if separate estimates of peak-hour traffic are required, it may be necessary to use 2



TO CALCULATE THE MINIMUM SIZE OF A SAMPLE, PLOT THE ESTIMATED PERCENTAGE OF BY PASSABLE TRAFFIC, (IF NOT KNOWN ASSUME 50%) AND THE REQUIRED ACCURACY IN THE ESTIMATE OF THE PERCENTAGE; THE SIZE OF SAMPLE MAY THEN BE READ FROM THE VERTICAL SCALE.

SAMPLING DIAGRAM FIG 25

or 3 questioners in the peak periods; however, it would be better to use one questioner and spread the survey over several days.

176. In the case of a large scale origin and destination survey the ultimate object will usually be to estimate the volume of traffic at some future date on particular roads, either existing or proposed. The sampling errors due to chance will again depend on the size of the sample. This can conveniently be expressed in terms of the sampling fraction k. In the case of a home interview survey k is the proportion of households interviewed. In the case of a cordon survey k is the ratio of the number of vehicles interviewed to the total number passing the cordon during the period covered by the survey. The estimate of the volume contributed by all households (or from all the interview points) to a road with an average volume m vehicles during the period covered by the survey will be between $m-2\sqrt{\frac{m(1-k)}{k}}$ and $m+2\sqrt{\frac{m(1-k)}{k}}$ approximately. If k is small then the expression for the limits may be simplified by removing the term $(1-k)$. It should be noted that in a cordon survey the term 'period of the survey' refers to the total time that each site was manned for interviewing; in a home interview survey it would refer to the period for which data were collected from each household. If 25% of the households in a town were asked about their journeys on the day previous to the interview then although the interviews were spread equally over a number of days the period of the survey would be 1 day and k should be equal to 0·25.

177. The sampling fractions required for a given accuracy at various levels of traffic in large scale surveys are given in the following table.

Table 3

Number of vehicles passing along the road during period of survey	Sampling fraction required to give errors in estimates of flow on a road within following range on 95% of occasions		
	±5%	±7½%	±10%
	%	%	%
500	75	60	45
1,000	60	40	29
2,000	45	26	17
5,000	24	12	7
10,000	14	7	4
20,000	7	3·4	2
50,000	3·1	1·4	0·8
100,000	1·6	0·7	0·4

It should be emphasised that these errors refer only to estimates for the period actually covered by the survey. Additional errors will be introduced if estimates are made for other times of the year or future years.

178. The sampling fraction required is the one which gives the greatest acceptable error for the road carrying the least volume of traffic, of those for which an estimate of volume is required.

Journey Times, Speeds and Delays

179. It is generally convenient to convert journey times (see paras 108–116) into speeds between major intersections (i.e. controlled intersections, roundabouts, etc.). This information can conveniently be transferred on to a map such as shown in Fig 26: the delays at controlled intersections will be listed. It is also helpful in order to draw attention to the worst sections of road to shade the roads in accordance with the speed of travel.

Accident Studies

180. The aim in accident studies is to find what can be done to reduce the number of accidents. A useful method is to make a visual analysis of an accident map and this will reveal concentrations of accidents at certain points which should be examined in greater detail to suggest possible remedial measures. The type of accident occurring often suggests features which should be looked for in subsequent examination.

181. In considering what measures may reduce accidents at a particular site a site inspection with police officers is invaluable coupled with discussion of those details of the accident or accidents which are not disclosed in the police reports. Although accidents are seldom directly attributable to the road layout, a variety of minor factors such as visibility play an important part. Officers engaged on this type of work should have practical experience allied to acute observation.

182. The plotting of accidents on key maps was referred to in para 124. A map scale of 1/2,500 is useful, although 6 in to 1 mile may be convenient if a length of several miles is involved. It will be helpful to indicate road features, road signs, white lines, pedestrian crossings, traffic signals, bus stops, etc., and also fronting land uses on the map.

183. The accidents may be denoted by a circle with a reference number, the circle being joined by a line to the point on the road where the accident happened. Where more than one accident occurs at the same point the circles are placed adjacent to one another. The amount

of detail recorded is a compromise between the desire to show up as many compromise factors as possible and the need for clarity. This is largely a matter of judgement based on local knowledge but the following are considered to be important and should always be recorded.

Reference number
Severity
Whether pedestrian involved
Whether vehicle skidded.

184. The reference number (usually that given by the police is placed inside the circle) enables quick reference to be made to the complete details of the accident. The severity can be denoted by the colour of the circumference of the circle and the following colour code is suggested for uniformity:

Fatal	red	ring
Serious Injury	blue	ring
Slight Injury	green	ring
Damage only	black	ring

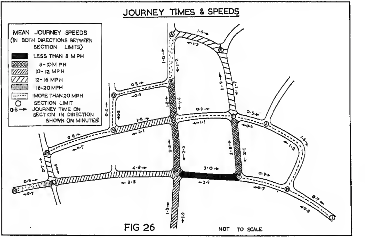
185. If a pedestrian is involved it is suggested that the inside of the circle be shaded red (light enough to permit the reference number to be seen). If a vehicle skidded the letter S should be placed by the side of the circle.

186. Other information can be recorded by shading the insides of the circles in various colours. A scheme which has been used is as follows:

Pedestrian involved	red	shading
Pedal cyclist involved	blue	shading
Vehicle/vehicle collision	green	shading
Vehicle collision with stationary vehicle or other object	yellow	shading
Passenger boarding or alighting a vehicle	orange	shading
Others	grey	shading

187. These categories are not mutually exclusive and some judgement may be necessary in classifying an accident to bring out what is likely to be the most important factor. For example if two vehicles collide and also strike a pedestrian it is probably better to classify the accident as 'pedestrian involved'.

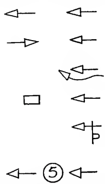
188. If the adequacy of street lighting is in question an analysis into daylight and dark accidents may be made by shading half the circle for daylight accidents and the whole of the circle for dark accidents.



JOURNEY TIMES & SPEEDS

FIG 26

189. The greatest concentrations of accidents usually occur at road junctions and it is often desirable to analyse the accidents in greater detail at these points. For this purpose a plan of the junction to a scale of at least 1/500 is required showing the kerb lines, building boundary lines, hedges and other obstructions, refuges, pedestrian crossings, white lines and street furniture. The paths of vehicles and pedestrians prior to the accident may be shown on the plan by means of arrows, and stationary vehicles by means of a rectangle. Examples of accidents denoted in this way are:



head to tail collision

head on collision

right turn and overtaking vehicle

collision with stationary vehicle

pedestrian knocked down by vehicle

Where a number of accidents of the same type occur they may be shown by a circle with the number inside it rather than being shown separately, for example:

5 head to tail collisions

190. The amount of further detail which is included is again a matter of judgement but the following classification into vehicle types by colouring the arrows or rectangles has been used:

Motor cycle	green
Car	black
Goods vehicles	brown
Bus	yellow
Pedal cycle	blue
Pedestrians	red

Parking Studies

191. The information obtained from the inventory of parking space is most conveniently plotted on a 1/1,250 map of the area, since the distribution of parking spaces throughout the town is perhaps of even greater importance than the total amount. It may be convenient to divide a large town into a number of areas with a separate map for each. The maps can usefully show the land uses in the vicinity of parking spaces.

192. The information from the parking usage study may be analysed in a number of ways. In the first place the variation in the concentration of parked vehicles throughout the day is of importance. Fig 27 for example shows the variation in the number of vehicles parked on the streets in a central area between 8.30 am and 6.30 pm on an average weekday. The peak of parking in this area occurs around 1.30 pm. If p is the number of vehicles parked in a street and P the number of 20 ft long kerb spaces available, then a parking index defined by

$$\frac{100p}{P}$$

may be used to assess the relative amounts of parking in individual streets. It is usual to show these indexes street by street on a map of the area by numbers (shading could be used) for the vehicles parked at the peak period.

193. In the larger towns it is frequently useful to be able to compare the concentration of parking in one area with that in another. For this purpose the average parking index for each area is used. This is illustrated in Fig 28. The analysis of a parking duration study consists of determining the number of occasions on which a given vehicle is seen. The results are usually presented

in tables in two ways which, whilst superficially similar, give two distinct and necessary pictures of the parking pattern. In the first the period of peak parking is selected and the vehicles seen during this period are analysed according to the duration of their stay. Table 4 for example gives some results for central London.

194. Such a table gives an estimate of the peak demand for parking and enables the effect of measures such as restriction of parking to under 2 hours to be judged in terms of the number of off-street spaces which would be required to cater for the displaced vehicles.

195. The second presentation relates to the total number of different vehicles seen throughout the period of the survey. This gives the total parking turnover and enables the revenue which might be expected to accrue from any system of paid parking to be calculated though the effect of paying for parking reduces the amount of parking. Table 5 gives the results for the period 8.30 am to 6.30 pm for the same area as Table 4.

Table 4: Peak use of street parking spaces

Number of Times seen	1	2	3–4	5–8	9–12	13–20	21 and over	
Approximate Duration of parking	½ hour	1 hour	1½–2 hours	2½–4 hours	4½–6 hours	6½–10 hours	Over 10 hours	Total
Total vehicles	2,910	2,358	5,651	6,848	7,952	12,560	1,344	39,632
Percentages	7·4	5·7	14·3	17·3	20·1	31·9	3·3	100·0

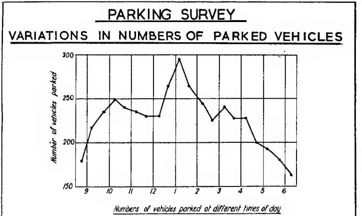


FIG 27

Table 5: Turnover of parking spaces

Number of Times seen	1	2	3–4	5–8	9–12	13–20	21 and over	
Approximate Duration of parking	½ hour	1 hour	1½–2 hours	2½–4 hours	4½–6 hours	6½–10 hours	10 and over hours	Total
Total vehicles	50,768	25,872	26,416	19,616	10,048	12,560	1,344	146,624
Percentages	34·6	17·7	18·0	13·4	6·8	8·6	0·9	100·0
Vehicle-hours of occupation	25,384	25,872	46,228	63,752	52,752	103,620	13,440	331,048
Percentages	7·7	7·8	14·0	19·3	15·9	31·2	4·1	100

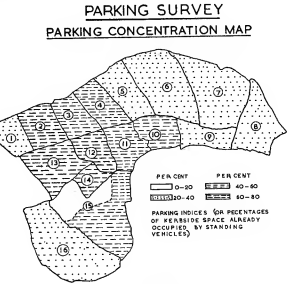

PARKING SURVEY
PARKING CONCENTRATION MAP
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
PER CENT
0–20
20–40
PER CENT
40–60
60–80
PARKING INDICES (OR PECENTAGES OF KERBSIDE SPACE ALREADY OCCUPIED BY STANDING VEHICLES)

FIG 28

PART 4

Formulation of Proposals

Introduction

196. Methods of dealing with the road system of an urban area fall broadly into two groups, firstly, the carrying out of short-term measures for making the best use of the existing road network, and secondly long term proposals which will need to form part of the land use/transport plan for the whole of the town.

197. In the text which follows short term measures are, as far as possible, dealt with first under each main heading.

198. When considering short term measures it is desirable to plan also for longer term schemes, owing to the rapidity with which traffic growth may absorb the additional traffic capacity provided, and the time required before longer term schemes can be commenced.

199. Even for the most urgent short-term schemes it is to be stressed that a wider appraisal is needed and whole routes or networks of roads should be considered before formulating proposals, as experience has shown that a piecemeal approach to traffic problems is generally unsatisfactory. It is often found that improving one junction may emphasise the difficulties at a neighbouring junction where conditions were becoming critical.

200. Traffic regulation is an important means of securing quick relief from urban congestion and whilst hitherto powers have only been available for making regulations of a permanent nature these powers have been extended by the Road Traffic Act, 1962 to cover experimental schemes (excepting in the City and Metropolitan Police District where powers for carrying out experimental schemes were already available). As the enforcement of traffic regulations will be carried out by the Police, close collaboration with them in formulating proposals is essential: police views on improvement schemes can also be of great assistance.

201. The use of these experimental powers will be found particularly helpful in enabling schemes to be tried and amended to best meet traffic conditions before permanent regulations are made.

202. When preparing medium and long term proposals it is essential to bear in mind that the aim should be to achieve a viable land use/transport plan for the whole urban area; this plan will need to include a progressive balanced improvement of the road network, parking provisions, and the urban development which generates the traffic. Only in this way can the basic causes of traffic congestion and accidents be avoided or dealt with. Solutions to traffic problems will also have to be weighed against the cost of schemes or the effect that a scheme may have on environment.

203. Measures of restriction and regulation, although relatively inexpensive, are seldom popular but they may be more readily accepted if clearly seen as part of a plan to provide the town eventually with sufficient means of traffic circulation.

Appraisal of Survey Results

204. The information obtained by the surveys carried out in accordance with the foregoing sections may be categorised into three classes.

(a) Journey speeds, running speeds, delays at intersections, and accident information.

(b) Traffic volumes, direction of traffic movements, parking surveys and details of bus services, etc.

(c) Growth of traffic, traffic distribution and land use and other planning surveys and proposals.

205. Whilst the information contained in (a) gives the measure of adequacy or otherwise of the roads concerned, it will be possible from (b) to gauge the nature of such measures as are required to meet these existing conditions and from (c) to assess how long these measures will meet the growth of traffic in advance of the implementation of a long term solution to the problem.

Application of Survey Results

206. The estimates of future traffic derived from studies of existing movements, growth rates and redevelopment may show that there is demand in an area for road space and parking facilities which are beyond that which it seems practicable to provide: it is particularly important in such cases that a decision on the long term solution should await the completion of the land use/transport plan for the town. This will need to be tackled by comprehensive surveys, which will include on the transport

side, the movement of goods and people by private vehicles, goods vehicles, public service vehicles and railways. The Buchanan Report makes it clear that the smaller the town the greater is the practicability of formulating a plan to accommodate a high proportion of potential traffic. The need for a comprehensive survey will therefore usually be of first priority in the larger urban areas where traffic difficulties are greatest and the issues involved more complex.

207. In designing road improvements full consideration should be given to:

1 Accident Prevention	by minimising the volume of traffic in residential and shopping streets and
2 Traffic Convenience	by providing an adequate and suitably located primary network for future through traffic and local traffic between the various parts of the town. The needs and convenience of pedestrian traffic must also be allowed for.
3 Amenity	by providing environmental areas with suitable distributory road networks.

208. To achieve the best type of improvement will require close collaboration between engineers and planners. Only by this collaboration is it likely that the urgent short to medium term measures will contribute to or form part of the long-term plan which will eventually emerge.

The General Road Network

Traffic Regulation

209. Some of the most useful short-term measures to consider are the banning of right turns, the making of one-way streets or a combination of both these methods. Sections (a) and (b) of Memorandum 747* (revised 1962) deal with the general considerations for the introduction of one-way streets and the banning of right turns and should be referred to.

210. One of the major causes of loss in traffic capacity and consequent delays in city streets is right turning traffic at road junctions. The position may be remedied either by banning right turns or making the streets in question one-way only or on dual carriageways by closing openings in the central reserve. The disadvantage of banning right turns lies in finding alternative routes for the displaced traffic and a succession of right-turn bans on a route may cause a serious cumulative effect at the first junction where they are permitted. The solution is often to displace these turns to a roundabout or to arrange one junction to cater for them. When producing a comprehensive scheme for eliminating right turning traffic, it is often best to make a number of the side streets one-way – this is often desirable in any case due to their narrow width – to route right turning traffic via these streets.

211. Some ways of re-routeing right turning traffic are shown in the arrangements numbered 1 to 5 in Fig 29. The selection of any particular method is dependent largely on the road layout and configuration of side streets, on the environmental conditions which will be created for frontage property to those streets, and also upon the extent to which extra capacity on the main road is required.

212. In many cases methods 3 or 4 may be satisfactory from the traffic aspect, particularly where the volume of right turning traffic can be accommodated in the gaps between successive traffic phases on the main road: these arrangements are not suitable on narrow roads (less than 3 lane carriageways) as the vehicles waiting to turn would impede other traffic. Methods 1 and 2 (sometimes known as the 'G' turn) have the advantage that as the right turning traffic becomes straight traffic at the major junction it can flow at highest saturation.

213. Method 5 (sometimes known as the 'Q' turn) although having the advantage as in 1 and 2 of converting right turning traffic into straight moving traffic has the disadvantage of passing traffic twice through a junction: it also has the disadvantage of causing a long detour. It may be appropriate where only a small volume of right turning traffic is concerned (say about 100 vph).

214. The making of one-way streets on the other hand can, if the scheme is well designed, have advantages for traffic over those obtainable by banning right turns, for example:

(a) It increases the capacity of the roads between intersections by between 20 and 50%, the higher percentage being obtainable on narrow roads (see Road Capacity, Table 6).

(b) Greater safety is obtained both for vehicular traffic and pedestrians by the simplification of traffic conflicts.

(c) Better crossing facilities for pedestrians can often be provided.

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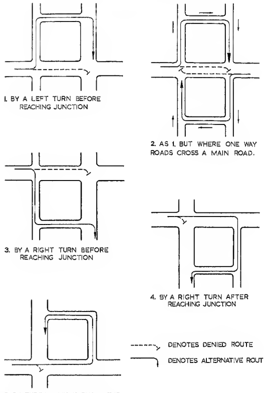
* A Planning Bulletin will supersede this memorandum and will be published shortly.

METHODS OF RE-ROUTING RIGHT TURNING TRAFFIC



1. BY A LEFT TURN BEFORE REACHING JUNCTION

2. AS 1, BUT WHERE ONE WAY ROADS CROSS A MAIN ROAD.

3. BY A RIGHT TURN BEFORE REACHING JUNCTION

4. BY A RIGHT TURN AFTER REACHING JUNCTION

5. BY THREE LEFT TURNS AFTER PASSING A JUNCTION

FIG 29

(d) Traffic signals along a one-way route can be phased on a simple progressive pattern so that traffic may traverse the route at a selected speed without interruption. Whilst a similar arrangement may be possible on a two-way street, it is generally not so satisfactory and often necessitates some compromise in the signal plan. The use of different signal plans at different peak periods of the day may sometimes be advantageous. Paragraph 355 deals with this aspect more fully.

215. A particular disadvantage is that from the diversion of considerable volumes of traffic forced to make detours, often long, with the result that this traffic not only has to travel greater distances but the traffic volume en route increases generally with the increased length of detour. Fig 30 shows, for example, how the volume of traffic on each arm of a triangular road pattern made one-way increases by 50%. If such a network embraced a large area of a town the capacity of the roads and particularly the junctions may be overtaxed due to this increase in flow. On the other hand traffic capacities of some junctions may be greatly improved due to the simplification of the traffic movements. It is accordingly essential to consider fully the effects of one-way schemes on the individual road junctions throughout a scheme.

216. For this purpose it is necessary to prepare plans showing the present and projected traffic pattern so that a clear assessment can be made. Whilst the preparation of this plan may often be carried out by deducing the traffic for the projected one-way system from the existing traffic volumes, it may be found necessary in some cases to take a small origin and destination survey to determine local traffic movements.

217. Alternative schemes must be compared, including those where right turns are banned so that the best system can be obtained. In considering the traffic merits of such schemes due regard should be given to the improvement in traffic capacity and the saving in journey times which are discussed further in paragraphs 457–462.

218. Although in most instances one-way schemes have been introduced as temporary measures pending redevelopment, consideration should be given to the adoption of one-way systems as part of the permanent layout of a road system where this is advantageous and consistent with the environmental area concept:

(a) On main routes where parallel roads of similar width and character can be provided not too far apart – preferably less than 300 yards (so that users of public service vehicles are not materially inconvenienced and detours for traffic are kept to a minimum.

(b) Where required for restraining ring road or by-pass traffic from cutting across central areas of a town instead of continuing on the ring road or by-pass.

(c) On secondary roads or minor streets where it is necessary to simplify the traffic control system at an intersection with a main road: similarly in cases where a main intersection requires improvement by the banning of a right turn and an alternative one-way route for right turning traffic is provided through a secondary road.

Closing of Side Streets (to Vehicular Traffic)

219. Whilst the dangers or congestion arising from side road connections with main roads can be relieved by restrictive measures as described above, there are instances, for example, where there are numerous lightly trafficked side roads along an important main route, or a side road junction near a major intersection causes traffic difficulties, where the closure of side roads (or prohibition of vehicular traffic) may be advantageous. Some of the advantages and disadvantages normally arising from closing side roads are:

Advantages

(a) An improvement in journey time on the main road. Journey time in traversing a road is closely related to the number of side road connections.

(b) A reduction in accidents. Accidents at lightly trafficked junctions are disproportionately high compared with junctions more heavily trafficked. There is also a large reduction in accidents when cross road junctions are converted to staggered junctions.

Disadvantages

(a) The increase in traffic volume at side road connections remaining may cause congestion or may necessitate the use of signal control.

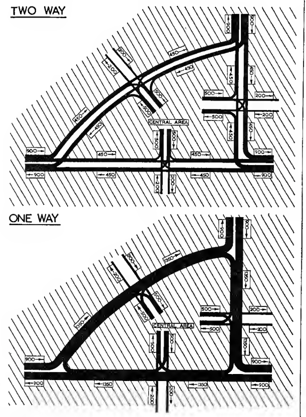
(b) Where side roads lead to rear accesses to buildings fronting a main road, their closure may encourage the waiting of vehicles on the main road.

(c) Side road connections are sometimes valuable for the diversion of right-turning traffic from a main intersection.

(d) Where main road intersections are overloaded or when road works are carried out side roads often afford in the short term the only alternative route for traffic.

220. It is therefore desirable when examining proposals for closing side roads to bear these various advantages and disadvantages in mind. On fast roads, where the

ONE WAY TRAFFIC SCHEME



DISTRIBUTION ASSUMED: FROM THE THREE APEXES
1/3 RD TO EACH AND 1/3 RD TO CENTRAL AREA:
FROM MINOR ROADS 100% TO CENTRAL AREA.

FIG 30

Table 6: Practical capacity of urban roads

TWO-WAY ROADS

Width: Effective width of Carriageway in feet (excluding refuges or central reserve)		Two-lane			Three-lane*		Four-lane			Six-lane		
		20	22	24	30	33	40	44	48	60	66	72
Type of road	**Description**	Capacity in PCU's† per hour Total BOTH directions of flow					Capacity in PCU's† per hour For ONE direction of flow					
A	Urban Motorway (Limited User), No Frontage Access, Grade Separations at Junctions								3,000			4,500
B1	All Purpose Road, No Frontage Access, No Standing Vehicles Permitted, Negligible Cross Traffic.	1,200	1,350	1,500	2,000	2,200	2,000	2,200	2,400	3,000	3,300	3,600
C1	All Purpose Street 'No Waiting' Restrictions on Parking of Vehicles, High Capacity Junctions.	800	1,000	1,200	1,600	1,800	1,200	1,350	1,500	2,000‡	2,250‡	2,500‡
D1	All Purpose Streets, Capacity Severely Restricted by Waiting Vehicles and Junctions.	300 to 500	450 to 600	600 to 750	900 to 1,100	1,100 to 1,300	800 to 900	900 to 1,000	1,000 to 1,200	1,300 to 1,700	1,500 to 2,000	1,600 to 2,200

ONE-WAY STREET

Width of Carriageway in feet		20	22	24	26	28	30	32	34	36	38	40	48
Type of road	**Description**	Capacity in PCU's† per hour											
B2	All Purpose Road, No Frontage Access, No Standing Vehicles Permitted, Negligible Cross Traffic.	2,000	2,200	2,400	2,600	2,800	3,000	3,200	3,400	3,600	3,800	4,000	4,800
C2	All Purpose Street 'No Waiting' Restriction on Parking of Vehicles, High Capacity Junctions.	1,300	1,450	1,600	1,800	1,950	2,150	2,300	2,450	2,650	2,850	3,000	3,700
D2	All Purpose Street, Capacity Restricted by Waiting Vehicles and Junctions.	800	950	1,100	1,300	1,450	1,650	1,800	1,950	2,150	2,350	2,500	3,200

* See paragraph 268 – the use of 3-lane carriageways for streets with high volumes of pedestrian traffic crossing them is to be avoided.

† See paragraph 54 – for Passenger Car Units (Urban Standards).

‡ For dual 3-lane carriageway roads it is considered that the capacity will be higher than the roads divided by refuges and the values given may be increased by 200 pcu's/hr.

concentration of side road traffic at one or two junctions will not cause traffic difficulties or where all the side road connections can be eliminated, these closures often effect a substantial reduction in accidents but on slow roads in central areas, the extensive closing of side roads is of more limited application. Where, however, it is advantageous to close a number of side roads and this results in providing signal control at a remaining junction it is important that this junction should be located at a suitable distance from other signal controlled junctions so that an efficient linked signal system can be provided. Satisfactory spacing between linked junctions on a two-way street is usually of the order of 300 yards and this aspect is of particular importance when replanning the road system in a central area.

221. The extent to which closed carriageways may form part of a system of pedestrian ways or for parking should also be considered.

By-passes, Relief and Ring Routes

222. In most towns the central business and shopping areas are traversed by through traffic and, taking into account the preservation of the local character of the area, general road safety, and the fact that central area redevelopment is a long-term solution, it is important to consider to what extent through traffic could be diverted from such areas by a by-pass or relief road.

223. In most of the larger towns there are also busy shopping centres on the main radial roads and consideration should be given to moving the shopping centres or diverting the traffic to relief roads.

224. In some towns ring routes are appropriate for diverting from the centre of a town a large volume of local circulatory traffic and will normally encompass the central business area. In the larger towns the ring route should be located far enough out to allow for the operation of a separate inner system of distribution streets to serve central area traffic. In many medium sized towns where the proportion of through traffic is not high, it may be found economic for the ring road to serve a dual purpose and designed to accommodate through as well as local traffic (bearing in mind that car parks, bus and coach stations and railway stations may be sited within the ring). It is to be noted that ring road systems must also accommodate radial traffic using the ring route for distributory purposes.

225. In each case estimates will be needed of the traffic volumes diverted to the new road and this will depend on its siting: alternative layouts can be compared by the methods given in Part 5.

Parking Places

226. Surveys as to parking requirements, trends in the growth of commuter traffic, the effect of public transport and the planning and redevelopment of the area should all be taken into account in determining the siting and the amount of car parking accommodation required. Such accommodation may be in the form of waiting within the time limits allowed by waiting restrictions, parking meter sites and other street car parks or off-street car parks for short-term parking requirements, and off-street surface areas or multi-storey car parks for long-term parking.

227. Reference should be made to current government publications on these subjects.

228. It is of particular importance to ensure that car parks are sited and designed so that:

(a) When the car park is being filled or emptied it does not cause congestion on the road to which it has access. This requires careful siting of the park itself and also of individual accesses. It may also be necessary to limit the capacity to about 500 vehicles, and it is often better to have several car parks of low capacity than a few car parks of high capacity. The effect on other roads in the locality must also be studied as the sudden disgorging from the car park at peak times may well create heavy right turning traffic at important junctions.

(b) As the demand on a car park used largely by commuter traffic may amount to about half the capacity of the car park in half an hour, it is essential that it should be designed to ensure that the car park can be filled at this rate so as to prevent any tail-back of vehicles on to the public highway; a similar rate is desirable for the discharge of vehicles. For surface or ramped car parks care is necessary in the siting of ticket offices and in deciding on the method of taking payments. For car parks with lifts an adequate number of lifts is essential (the rate of lift operation is usually about one vehicle per minute), and it is also necessary to provide an area off the street for vehicles waiting to enter the lifts; 10% of the total capacity is sometimes considered to be appropriate for this.

The Road Between Junctions

Road Capacity

229. Before an appreciation can be made of the need for waiting restrictions or the widening of carriageways, it is necessary to know the capacity of a road under

varying widths. It is difficult to forecast in a precise way such information due to the variety of conditions on a road. For instance, the volume of pedestrians crossing in shopping streets, frequency of minor intersections, the amount of turning traffic, the effect of standing vehicles and degree of enforcement of waiting restrictions all effect road capacity. However, the limitations on capacity imposed by signal controlled junctions will generally be the determining factor of the capacity of a street.

230. Bearing in mind these points Table 6 gives an indication of the approximate traffic capacity of roads between junctions.

231. It will be recalled that in paragraph 33 it was indicated that, unlike rural roads which should be designed on the basis of the total daily flow, urban roads require to be designed on the basis of *peak-hour demand*. Subsequently methods were described for obtaining estimates of appropriate peak-hour traffic volumes in each direction of a road.

232. The capacities given in Table 6 should therefore be applied so that for divided roads the design is based on the peak flow in the heavier direction of travel, and as undivided roads permit greater flexibility in the ratio of opposing flows, their design is based on the maximum total flow (total for both directions). These capacities rely on the principle that in urban conditions drivers are prepared for and accept lower speeds and less overtaking than on rural roads.

233. With regard to the application of these standards, it is considered that whilst Type B would be generally applicable for ring roads and important radial routes, Type C would be applicable to other radial routes and main roads where accesses due to development are frequent but where the capacity is not unduly restricted by important junctions. Type D is applicable to typical

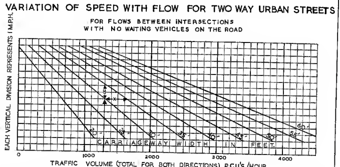


FIG 31

Where it is required to estimate the effects of widening a carriageway where observations on flows and speeds have been taken, first plot a point corresponding to the *observed flow* and *carriageway width* then:

To Estimate the increased SPEED (for the same flow as observed) extend a line *vertically* from the point plotted or cut a line corresponding to the increased width and read from the vertical scale the increase in speed (between the two points), add this to the observed speed to find the estimated SPEED.

To Estimate the increased CAPACITY (for the same speed as observed) extend a line *horizontally* from the point plotted to cut a line corresponding to the increased width, read the horizontal scale for this point to find the estimated CAPACITY.

EXAMPLE: Observed speed – 17 mph, observed flow – 1,300 pcu's/hr, Existing carriageway width – 30 feet, proposed carriageway width – 35 feet.
INCREASE in capacity (at 17 mph) = x = 350 pcu's/hr. Resultant Capacity 1,650 pcu's/hr.
INCREASE in speed (flow 1,300 pcu's/hr) = y = 2·3 mph. Resultant Speed 19·3 mph.

urban conditions where controlled junctions with heavy cross traffic and waiting vehicles severely limit street capacity.

234. For roads in outlying areas of rural character and by-passes (not usually subject to a speed limit), the design width should be in accordance with the standards set down in Memorandum 780 issued by the Ministry of Transport in 1961, which allows for higher speeds and freer overtaking.

Speed

235. On roads of limited access such as urban motorways or high-class routes (Types A and B in Table 6) it should be possible to attain average speeds under peak-hour conditions of about 35–40 mph.

236. For most main streets, however, the normal 30 mph speed limit would apply and, whilst speeds of 20–25 mph would be a desirable aim, the normal factors such as delays at intersections, bus stops, pedestrian crossings, etc, absorb so high a proportion of journey time that the highest capacities are obtained at low speeds. The improvement of journey speeds can only be ensured by providing adequate road and intersection capacity and minimising obstruction by waiting vehicles and right-turning traffic.

237. Fig 31 shows the variation of speed with flow for typical urban streets (exclusive of the effect of major intersections) with no parked vehicles present. Conditions vary considerably, so that the diagram may not give the same result as those observed on a particular street. If it is required to estimate the effects of widening a carriageway, the methods given in the diagram may be used. In the example given it will be seen that the widening of a 30 ft carriageway by 5 ft may be expected to produce an increase in speed of 2·3 mph, if the flow remains constant, or an increase in capacity of 350 pcu's/hour, if the speed remains constant.

Restrictions on Stationary Vehicles

238. The most readily applicable measure to improve traffic capacity is the making of Waiting restrictions either in the form of Unilateral Waiting, No Waiting (with or without loading and unloading restrictions), or Clearways. The general considerations to be borne in mind for unilateral and no waiting restrictions are given in Memorandum 747.* It should be noted, however, that paragraph 50 of that Memorandum as originally issued, is cancelled and reference should be made to Circular Number Roads 12/62 (Appendix) in connection with the new powers available under the Road Traffic Act, 1962 (Section 51): Section 28 of this Act also gives powers for experimental traffic schemes. Reference should also be made to Circular No. 798 which gives the requirements for Clearways. The Technical Standards for Clearways given in Appendix A to that circular show that there can be only limited application in most urban areas of that form of restriction, but similar improvements in road capacity can be secured by restrictions on loading and unloading and if necessary on the stopping of vehicles. These restrictions can be applied during one or both peak periods of the day so as to reduce the inconvenience to frontagers or callers, etc: the restrictions may be further modified by being applied only to the side of the road carrying the heavier traffic flow during the peak period.

239. As due regard must be given to the normal business activities on a road, the severity of the restrictions should be appropriate to capacity requirements and a general guide can be obtained by reference to Table 6 for the capacity of urban streets under differing conditions. These street capacities should not, however, be applied rigidly as it may be found that the control at major intersections (where there is no parking problem in the vicinity of the junction), results in capacities that would not be improved by waiting restrictions; or on the other hand that a particular road having infrequent junctions or other impediment to traffic has adequate capacity without restrictions being necessary.

240. Where roads are congested and traffic volumes are high in relation to the road widths, exceeding the capacities gvien for Type C in Table 6 consideration should usually be given to restrictions which will eliminate standing vehicles at times of congestion. If the road is of suitable standard then Clearway restrictions may be appropriate. Where the roads are unsuitable for Clearway restrictions then the appropriate measure may be No Waiting restrictions with additional restrictions at peak times as described in para 238. It will be appreciated that No Waiting Orders normally provide exemption for vehicles stopping to pick up or set down passengers or loading and unloading of goods.

241. Where congestion occurs on less heavily trafficked roads but where the volume exceeds the capacities given for Type D in Table 6 there are usually grounds for restricting Waiting either throughout the road, on the approaches and leaving sides of junctions, or at bottlenecks.

242. Waiting restrictions are particularly beneficial where parking is extensive and traffic flow is impeded by

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* Memorandum 747 (revised December 1962 and by amending Circulars). A Planning Bulletin will supersede this memorandum and will be published shortly.

double banking, due to goods vehicles and buses being unable to load at kerbside positions. The full capacity of a road, however, can seldom be achieved by waiting restrictions alone, due to the stopping of vehicles exempt from the restrictions, and the resulting improvement in capacity is largely dependent upon the number and location of these exempted vehicles.

243. The effect on road capacity of parked vehicles is not proportional to the numbers parked. Table 7 below gives an indication of the effective reduction in carriageway width produced by various numbers of parked vehicles per mile, and as an example the corresponding loss of capacity if a speed of 15 mph is to be maintained.

Table 7

Parked Vehicles per mile (both sides together)	5	10	50	100	200	500
Effective loss of carriageway width in feet	3	4	7	8½	10	12
Loss of capacity at 15 mph (pcu's/hr)	200	275	475	575	675	800

244. It will be seen that small numbers of parked vehicles have relatively large effects in reducing capacity, and that the effect of a given increase in parking diminishes as the intensity increases. This means that waiting restrictions may only have a limited effect on the capacity of a street along which a few vehicles loading and unloading are distributed. Even a single standing vehicle may cause serious congestion particularly when near a junction, a busy crossing or at a bottleneck.

245. If the volume of traffic is maintained parked vehicles also reduce the speed of traffic, even when volumes are light. The results can be found by referring to Fig 31 and Table 7. For instance, on a 30 ft carriageway on which 1,400 pcu's/hr travel at 15 mph in the absence of parking, the speed would be reduced by about 5 mph if there were 50 parked vehicles per mile. Also with capacity, the effect of a given increase in parking is much smaller at higher levels of parking intensity.

246. The value of access from the rear to buildings fronting busy roads cannot be overstressed. The problem can, however, sometimes be eased temporarily by local carriageway widenings which it is frequently possible to carry out in advance of more comprehensive widening schemes. It needs to be remembered that widening schemes should not often have a place in solving the traffic problems of important shopping streets; a local carriageway widening which would be useful in the short term may thus be difficult to assimilate into a final scheme in which the street becomes a pedestrian shopping way.

247. Apart from these aspects it is often shown that a number of accidents occur in streets where parking is prevalent due to pedestrians crossing the road between parked vehicles and being unable to see or be seen by approaching traffic. It is to be stressed that waiting restrictions not only assist in improving traffic flow but also have a bearing on the improvement of the accident record.

248. In streets where waiting is prohibited on one side and vehicles may wait on the other side for a limited period, usually between 15 and 30 minutes, difficulties sometimes arise as to the enforcement of this time limit. The problem is particularly serious in large towns and is, of course, largely overcome by the introduction of parking meter schemes where the enforcement is carried out by traffic wardens. Parking meter schemes also improve traffic flow due to the precision with which kerbside areas may be allocated for parking or loading, with resultant reduction in delay from 'double banking' or from vehicles manoeuvring into cramped positions.

Tidal Traffic

249. Although the use of carriageways permitting some traffic lanes to be used in the reverse direction at peak times has only been applied in this country to a few special instances such as at bridges and tunnels, its application is more widespread in the USA and consideration may be given to such a scheme where it is warranted. It is, however, important that the following conditions are met:

1. The difference between the flows in the two directions is substantial, being at least sufficient to justify an extra lane in the direction of major flow.
2. Adequate capacity cannot be obtained by the restriction of parking and right turning traffic or other means.
3. The congestion occurring results in substantial delay to traffic and it is limited to specific times of the day.
4. The capacity provided for the lesser flow shall be adequate.
5. Where only one lane is available for the lesser flow all forms of waiting can be prohibited. Such systems should be confined to short lengths of roads, bridges, etc, in view of possible congestion from breakdowns which are more likely to occur on longer lengths of road.
6. The terminal arrangements for merging the normal and reversed flow lanes are satisfactory.

250. On narrower streets of 4 lanes width or less, it may be preferable to consider making the whole street one-way at peak periods and two-way at off-peak times. Such a system needs particular care in sign posting as it presents a greater danger than the normal tidal system to the unobservant motorist. Satisfactory alternative routes are needed for traffic in the reverse direction. Such a scheme is easier to apply to roads with few junctions.

251. Reversible flow systems require particular attention as to the method of operation, owing to the danger of head-on collisions if the system is not manifestly clear to road-users. The two systems in general use are:

1 By signs provided along carriageways to inform road-users of the number of traffic lanes available in each direction at different times of the day. In addition, it is usually desirable to supplement these signs by placing rubber cones or other devices to mark out the carriageway widths available in each direction at the ends of the system and along the road. At times of reversal it is usually necessary to patrol the roads to clear the appropriate lanes and resite the cones, etc.

2 By overhead illuminated signs placed above the road over the centre of each lane indicating either a red cross or green arrow according to the direction of travel permitted. Such signs require to be placed at, say, 300 yards apart along a road, and are usually operated so that, at each changeover, the green arrow for lanes to be reversed in direction, are changed in succession to clear the traffic before reversal takes place.

Bus Stops

252. Buses form the principal means of transport for a large proportion of the population and bus stops should be best sited to serve the public. It is, however, desirable from the traffic aspect that bus stops should cause the least obstruction to traffic and care given to siting them. It is important that bus stops should not obstruct the approach or leaving side at controlled junctions or at roundabouts. The effect of a standing vehicle on the approach to traffic signals is given in paragraph 331 which gives an indication of the serious effect that a bus stop so located could have on the capacity of a signal controlled junction.

253. Bus stops on two or three-lane carriageways should be sited in staggered positions preferably so that on leaving the stops buses will move away from each other. The distance between the staggered positions should be adequate to allow overtaking vehicles to draw up preferably 75–100 yards.

254. Double-banking by buses outside a line of waiting vehicles can also be a source of considerable delay and the carriageway marking for bus stops given in the Traffic Signs Regulations and General Directions 1965, diagram 1025 can be effective from preventing other vehicles parking at the bus stop sites.

255. Consideration should be given to providing bus draw-ins where the capacity of roads is affected by bus stops. It is often possible to take advantage of sites where buildings have been set back for future widening to provide bus draw-ins in busy streets. Adequate space for pedestrian movement and for bus queues should be provided. The siting of bus stops for easy access to pedestrian subways should be borne in mind.

Traffic Signs and Carriageway Markings

256. As a new system of traffic signs is prescribed by the 1965 Traffic Signs Regulations a general review to see that the correct signs are being used and that they are well sited and maintained should be made: a new signs manual gives advice on these aspects. Unnecessary signs should be removed since excess tends to depreciate the value of signs. Special attention should be given to sites where accident studies suggest that the signs and carriageway markings may be unsatisfactory or warning signs required.

257. Well-sited warning signs of the right kind may be a valuable means of calling the drivers' attention to dangerous conditions, not otherwise apparent, at accident sites pending improvements. Such signs should not, however, be used where dangers are self-evident both by day and night.

258. Information and direction signs help to keep traffic flowing smoothly and to avoid accidents by eliminating indecision on the part of drivers. The complete system of through route direction signs in the town should be examined to ensure that the signs are well sited and in good condition give a clear message. Advance signs should give drivers ample time to make correct decisions. It is important that the junctions should not be treated in isolation for this purpose. There should be a complete system consistent within itself and correlated with signs outside the boundaries of the town. It is particularly important to ensure that the same place names are indicated consistently on each route. Street name plates and car park signs are also important and these should be clear and sufficiently frequent.

259. The double white line system shown in 1014 of the 1965 Regulation is not, in general, suited to urban areas.

260. The division of the carriageway into traffic lanes

can be an important means of increasing capacity particularly at the approach to signalled intersections. (See paragraphs 300–312 for details of layout at signal-controlled intersections.)

261. It is important that carriageway markings should not be laid in slippery materials, particularly at sites where there are appreciable numbers of two-wheeled vehicles.

Design, Widening and Realignment of Roads

262. The considerations to be taken into account in assessing the traffic that a road is likely to take will emerge in the formulation of the land use/transport plan or when the latter has not been carried out, from the surveys and census data referred to in this memorandum. In the latter case account will have to be taken of growth (see paras 21, 22, 141, 142, 168 and 169) as modified by the considerations given in paras 170, 171, and 206–208. The design width can be taken from Table 6 on the basis of no waiting vehicles being allowed; this assumption is based on the principle that, in a properly prepared plan, servicing of business premises will be provided for in the redevelopment of property. Where, however, old property remains on one side of the road it may be necessary to consider the provision of service lay-byes, additional to the normal carriageway width.

263. Inspection of the road and information from timed runs and accident records will reveal sections where bottlenecks, bends, visibility or surfacings require to be improved. Palliative measures can often be applied by means of traffic signs (see paragraph 257) or where skidding accidents occur, by resurfacing, but longer-term measures such as widening, realignment and super-elevation, are the only permanent effective solutions.

264. Often small widenings of a few feet will effect worthwhile improvements by increasing the road capacity in proportion to the increased width (see example paragraphs 444 and 445).

265. When selecting carriageway widths of suitable capacity for the expected future traffic, consideration should be given to the following points:

(a) The width selected, excluding refuges, should be a multiple of the width of a traffic lane.

(b) The width of a traffic lane should be 12 ft. Where lane widths have to be restricted to 10 or 11 ft their capacity will be reduced in proportion.

266. Obstructions near the edge of carriageways reduce capacity and are a source of danger. The effective width of a road may be reduced by about 2 ft 6 in if obstructions such as barriers, walls or posts are sited at the edge of the carriageway: the reduction is about 1 ft when the obstruction is 3 ft from the edge of the carriageway. It is therefore important that on high capacity roads such as Types A and B in Table 6 no obstructions are placed near the edge of carriageways and that on other roads such obstructions are kept to a minimum.

267. The crossing of busy streets by pedestrians is greatly facilitated by the provision of refuges and further reference is made later to this aspect. It is generally advisable that shopping streets should be provided with refuges of not less than 4 ft in width but the carriageway width on each side of the refuge should not be less than 20 ft. Refuges may be provided on slightly narrower streets, but below a total width of 40 ft there is a danger that parked vehicles may cause obstruction and furthermore the overtaking of slower vehicles may become a dangerous manoeuvre in such circumstances.

268. Three lane carriageways are accordingly unsuitable for streets with high volumes of pedestrian traffic crossing at surface level as central refuges cannot be placed in them.

(See paragraphs 402–416 for further information on pedestrian facilities.)

The Road Junction

General

269. The capacity of a road is in most cases determined by the capacity of its junctions and at signal controlled intersections road capacity is usually reduced to less than half its free running capacity. Furthermore, half of the fatal and serious accidents in urban areas occur at intersections. It is therefore of prime importance that attention should be particularly directed towards the improvement of traffic conditions at intersections either by means of restrictive measures, minor improvements, introduction of signal control, channelised systems, provision of roundabouts or combinations of some of these measures.

270. Flyovers or underpasses of various types ranging from simple grade separation for one stream of traffic only to full interchanges may be needed at the most heavily trafficked junctions. (See paragraphs 383–398.)

271. Standing vehicles should, wherever possible, be restricted in the vicinity of road junctions. The loss in capacity due to standing vehicles on the approaches to a signal controlled intersection is equivalent to the width

of a vehicle when it is within 25 ft of the stop line: the effect diminishes as the distance increases. (See paragraph 331.)

272. In designing road junctions calculations should always be made of the capacity needed to meet future traffic growth, and provision should be made for this if practicable. This should not, however, preclude the carrying out of junction improvements which will have a useful short term effect. The long-term improvement of junctions should provide sufficient capacity to meet the most unfavourable conditions obtaining in all parts of the junction. (Usually this will occur at morning or evening peak but exceptionally may occur at other times of the day.) This capacity should be determined from the smaller of either:

(a) The future traffic based on normal growth (see paragraphs 21, 22, 141–145, 168–169) as modified by the considerations given in paragraphs 170–171, 206–208.

(b) The maximum flow which the approach roads could feed into the intersection on the basis that all reasonably foreseeable improvements will be carried out, that no vehicles wait on the approaches, and that an appropriate directional distribution is assumed (normally for each approach the proportions of turning traffic would be assumed to remain constant). Such maximum flow volumes may be derived by adding 15% to the capacities of roads, Types A, B and C, Table 6. (This additional percentage is allowed as the tabulated capacities of roads have a greater 'factor of safety' than the practical capacities of signal controlled intersections or roundabouts.)

Principles of Design

273. The essential function of the design of a junction is to resolve conflict between intersecting traffic streams either by grade separation, signal control or by channelling traffic into the most suitable paths for cutting or merging with other traffic streams. In order that such movements can be carried out efficiently and safely drivers should be able to discern quickly either from the layout or from traffic signs the paths which they should follow and the actions of intersecting or merging vehicles.

274. Where traffic streams join, the layout should permit the merging of the two streams at a small angle and approximately equal speeds. Abrupt changes in speed of vehicles should be avoided by the suitable alignment of curves and tapers. These principles are, of course, of limited application in urban conditions, and apply mainly to major routes outside the central area, at some channelised types of junctions, or designs involving separation.

275. Stop positions, that is positions at which vehicles must wait for gaps in other traffic streams, should be clearly defined or marked so as to avoid misunderstanding and accidents: detailed advice on signs and carriageway markings is given in the Traffic Signs manual. Right turning traffic from the major road should be provided with a defined area in which to wait.

276. Traffic islands can be used advantageously in many cases to restrain traffic from taking paths that may be dangerous, for example, cutting curves or making right turns on a bend before a point of adequate visibility is reached around a bend.

277. Simplification of traffic conflicts can often be effected where left turning proportions of traffic are heavy by reducing the volume of traffic involved by giving left turn traffic a free movement away from the major point of traffic conflict. By this means the frequency of traffic gaps at the point of conflict is increased with consequent increase in capacity and reduction in delay. A similar reduction in traffic conflict is obtained by enabling side road traffic to cross dual carriageways in two movements – see following section.

Uncontrolled Junctions

278. The need to warn drivers from a side road entering a more important road depends on the traffic importance of the two roads and site conditions, particularly the length of visibility splays and the apparent relative widths of roads. Close study is essential both of accident records covering as long a period as possible and also of driver behaviour at the junction before it will be possible to decide on the appropriate road markings or signs which should be used.

279. Any doubt as to road priority can be resolved by the use of prescribed carriageway markings: for details see the Traffic Signs manual. At more important junctions or where there is a need on account of traffic importance of the route or danger to make a more emphatic distinction, 'Give Way' signs can be used in addition to the carriageway markings or if visibility is restricted, by 'Stop' signs and solid white lines. 'Stop' signs may only be provided with the approval of the Divisional Road Engineer and this is only given where visibility is so restricted that it is essential for a vehicle to come to a stop at the major road before proceeding: their use is of particular value until sight lines can be improved.

280. Where the major road is a primary route, precedence must be shown over all side roads and carriageway markings should be provided at all junctions and 'Give Way' or 'Stop' signs (as appropriate) at important or dangerous junctions in urban areas.

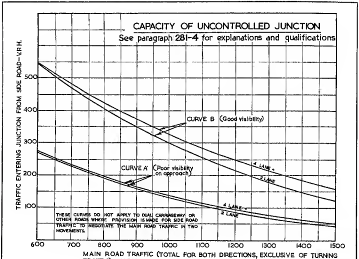


FIG 32

281. The capacity of uncontrolled junctions is, however, restricted as it depends on the frequency of gaps between vehicles in the main road flow which are of sufficient duration to permit vehicles from the side road to cross the main road. As, in general, the flow of traffic on a road approximates a 'random distribution', calculations may be made of the volume of side road traffic which may cross selected volumes of main road traffic based on minimum acceptable gaps and minimum vehicular spacing in the main and side roads.

282. Curve A in Fig 32 shows the maximum volume of side road traffic which may cross differing flows on the main road on the basis of a single lane approach, poor visibility from the side road, a minimum acceptable gap of 8 seconds. These conditions will apply when visibility is restricted on the approach but is adequate at the stopped position.

283. Under conditions of good visibility, permitting vehicles from the side road to enter suitably long gaps in groups without each vehicle necessarily having to stop at the major road, the capacity is increased as shown by Curve B. This curve is based on a minimum acceptable gap of 6 seconds.

284. These curves can only form a general guide to junction capacity in urban conditions as:

(a) Where traffic is unequally distributed between the two carriageways the capacity will be somewhat reduced.

(b) Where there is a high proportion of heavy vehicles or an up gradient on the side road longer gaps will be required and capacity will be reduced.

(c) The visibility conditions for Curve A assume adequate visibility at the stopped position and poorer visibility at that point may reduce capacity substantially.

(d) The effect of gaps in main road flow caused by signals or pedestrian crossings nearby may increase the capacity of the junction.

T JUNCTION WITH DUAL CARRIAGEWAY

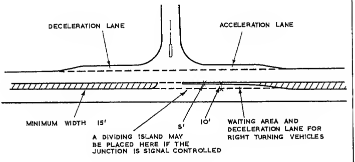

DECELERATION LANE
ACCELERATION LANE
MINIMUM WIDTH 15'
5'
10'
WAITING AREA AND DECELERATION LANE FOR RIGHT TURNING VEHICLES
A DIVIDING ISLAND MAY BE PLACED HERE IF THE JUNCTION IS SIGNAL CONTROLLED

FIG 33

285. From the curves in Fig 32 it will be seen that the capacity of an uncontrolled junction may be increased by improving visibility: it can also be increased by widening the side road near the junction so as to permit more than one vehicle to emerge abreast when traffic gaps are adequate. The full value of an extra lane will not be obtained when visibility is reduced due to vehicles waiting side by side.

286. Improved capacity can also be obtained where the main road has a central reservation and an opening is provided in which vehicles can wait and so carry out the cutting of the main road stream in easy movements. This method is best applied in the case of T junctions (see Fig 33) but it can be applied quite satisfactorily to cross roads. It is, however, important that the central reserve should not be less than 15 ft in width, preferably greater, and a local widening of the central reserve should be provided if this can be done without introducing serious misalignment of the main carriageway.

Criteria for Signal Control

287. With heavy traffic volumes at uncontrolled junctions delay to side road traffic becomes excessive and accidents and congestion result. Signal control must then be considered, though it must be stressed that where signal control is introduced the number of some types of accidents such as front to rear collisions may increase.

288. It is difficult to give firm criteria of minimum traffic volumes for traffic signal control without detailed

information as to the site layout, traffic distribution and types of accidents occurring. For conditions of good visibility uncontrolled junctions may well function satisfactorily with peak volumes entering the junction from the main road and from the more heavily trafficked side road totalling about 1,000–1,200 vph where the side road is of one lane approach width. Uncontrolled crossroad junctions are known where volumes in excess of 2,000 vph (evenly distibuted on each approach) enter a junction and traffic functions satisfactorily with a low accident record.

289. Where visibility is so restricted that only one vehicle at a time from the side road may enter gaps in the major flow it may be necessary to introduce control at much lower volumes. As, however, delays to main road traffic should be minimised as far as practicable it is preferable to consider what alternative measures are possible such as improving visibility or in some cases the diversion of traffic to another controlled junction.

290. A high proportion of accidents of types preventable by signal control is another justification, though the usual increase in head to tail collisions, already mentioned must be taken into account. An accident record of about 5 personal injury accidents per year of which a reasonable proportion would be preventable by signal control may be regarded as typical of conditions where signal control may be expected to cause a nett reduction in accidents. Traffic volumes at times other than at peak hours require study, so that the extent to which difficult conditions persist beyond peak hours may be determined; and a full day's census is required for this purpose.

291. When the accident record is low and it is proposed to provide traffic signals in order to reduce delay, a comparison may be made of the average delay to all vehicles under uncontrolled conditions with the delays which would occur if signals were provided. This should be done for both peak and off-peak conditions.

292. Under uncontrolled conditions the average delays to side road vehicles occurring can be found by the methods described in paragraphs 119–122; the delay to main road traffic is of course zero. For the delay at a signal-controlled intersection it is necessary to refer to Road Research Technical Paper No. 39 (Her Majesty's Stationery Office) or to use the approximate formula:

$$d=0{\cdot}9\left\{\frac{s(c-g)^2}{2c(s-q)}+\frac{1{,}800\ qc^2}{gs(gs-qc)}\right\}\ \text{Seconds per vehicle on each approach.}$$

$$\text{where}\quad \left.\begin{aligned} &c=\text{cycle time (seconds)}\\ &g=\text{green time (seconds)}\\ &q=\text{flow (vph)}\\ &s=\text{saturation flow (vph)}\end{aligned}\right\}\ \begin{aligned}&\text{for approach}\\ &\text{concerned see}\\ &\text{paras 326–332}\end{aligned}$$

293. Both for uncontrolled and signal controlled conditions delays will have to be derived for each of the approaches to obtain the total vehicular delay. This when summed over the approaches, divided by the total flow, gives the average delay to all vehicles.

Design of Traffic Signalled Controlled Junctions

General

294. Whilst there are many aspects of design to be considered to ensure that a proposed layout and traffic phasing will meet traffic and pedestrian requirements, the general procedure will normally follow the sequence given below:

(a) Traffic Diagrams: As the scheme must be designed to meet the worst conditions with some measure of reserve capacity, it is first necessary to have information on traffic volumes and distribution for each peak period and this should be prepared in accordance with the methods described in paras 43–48 and 145. Separate counts may be necessary for recurrent special conditions, e.g. market days.

(b) Layout and Phasing: (i.e. sequence of permitted traffic movements). The traffic diagrams should next be examined in conjunction with a large scale plan of the junction so that traffic phasing and modifications of the layout may be decided. As high capacity and small delay depend on keeping as much traffic as possible moving simultaneously, main traffic streams which do not conflict should be phased to run at the same time. See also paras 295–299.

(c) Capacity: When the layout and phasing plans have been prepared it is then necessary to check the reserve capacity provided and if this is not adequate a redesign may be needed. This may involve both layout and phasing since there is often interrelation between them.

295. The layout requires to be balanced as far as possible – that is, the distance between stop lines and possible traffic conflict points should be similar. The layout should also be compact so that clearance times between phases are kept as short as possible. This frequently necessitates adjustments to kerb alignment and may, if the junction is bell mouthed, require the provision of a triangular traffic island so that stop lines may be brought near to the junction. (Typical adjustments to layout are shown in Fig 36.)

296. Where the layout cannot be sufficiently balanced and conflict is likely to occur between vehicles clearing at the end of one phase and those starting at the beginning of the succeeding phase, an increased clearing

TYPICAL LAYOUT FOR TRAFFIC SIGNAL INSTALLATION

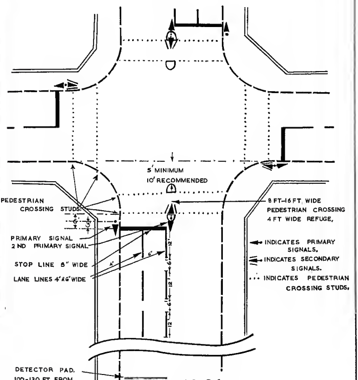

5' MINIMUM
10' RECOMMENDED
PEDESTRIAN CROSSING STUDS.
6"
3"
PRIMARY SIGNAL
2 ND PRIMARY SIGNAL
STOP LINE 8" WIDE
LANE LINES 4" & 6" WIDE
4"
6"
12'
6'
12'
6'
12'
8 FT–16 FT WIDE PEDESTRIAN CROSSING 4 FT WIDE REFUGE.
INDICATES PRIMARY SIGNALS.
INDICATES SECONDARY SIGNALS.
INDICATES PEDESTRIAN CROSSING STUDS.
DETECTOR PAD. 100–130 FT FROM STOP LINE.

FIG 34

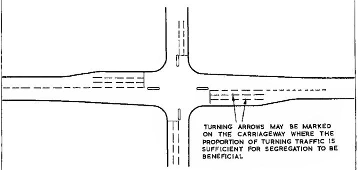
period is required between the phases. The increase in the clearing period to balance a junction is usually quite small, generally about one or two seconds. This is effected on modern controllers by adjustment of the 'intergreen' period (i.e. the time between the termination of the green on one phase and the commencement of the green on the succeeding phase). The minimum setting is 4 seconds (consisting of 3 seconds amber overlapped by one second of the two seconds red/amber signal preceding the following phase) and this may be increased by making the red/amber signal follow the amber signal (i.e. 5 second intergreen) or by interposing an all-red signal between the amber and red/amber signals (i.e. 6 or more seconds intergreen). On many older type controllers (where the amber and red/amber signals appear concurrently) no adjustment is possible but on some, increased clearance may be provided by making a 3 second red/amber follow the 3 second amber signal (i.e. 6 seconds intergreen or additionally by interposing an all-red signal between the ambers.

297. The extra clearing times should only be applied to the particular change of phase which requires it (i.e. for example, from A to B but not necessarily from B to A, where A and B are the two phases).

298. Clearance periods may also be increased to assist pedestrian movement or for clearing right turning vehicles at the end of a phase – the 'locking up' of a junction can often be prevented in this way.

299. Where more than two main phases are involved it is necessary to ensure that the sequence chosen results in the least loss in clearance time between phases. This feature is often of particular importance where a junction includes roads converging at a small angle. If, however, occasional absence of traffic demand results in the omission of a phase it is necessary to consider

SIGNAL CONTROLLED CROSS-ROADS WITH MAIN ROAD WIDENING



TURNING ARROWS MAY BE MARKED ON THE CARRIAGEWAY WHERE THE PROPORTION OF TURNING TRAFFIC IS SUFFICIENT FOR SEGREGATION TO BE BENEFICIAL

FIG 35

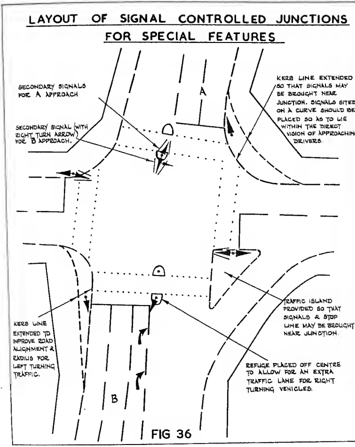

LAYOUT OF SIGNAL CONTROLLED JUNCTIONS FOR SPECIAL FEATURES
SECONDARY SIGNALS FOR A APPROACH
SECONDARY SIGNAL (WITH RIGHT TURN ARROW) FOR B APPROACH.
A
KERB LINE EXTENDED SO THAT SIGNALS MAY BE BROUGHT NEAR JUNCTION. SIGNALS SITED ON A CURVE SHOULD BE PLACED SO AS TO LIE WITHIN THE DIRECT VISION OF APPROACHING DRIVERS.
TRAFFIC ISLAND PROVIDED SO THAT SIGNALS & STOP LINE MAY BE BROUGHT NEAR JUNCTION.
KERB LINE EXTENDED TO IMPROVE ROAD ALIGNMENT & RADIUS FOR LEFT TURNING TRAFFIC.
REFUGE PLACED OFF CENTRE TO ALLOW FOR AN EXTRA TRAFFIC LANE FOR RIGHT TURNING VEHICLES.
B

FIG 36

whether a special clearance period must then be inserted.

Layout and Siting of Signals

300. As signal control requires the separation of traffic conflicts on a time basis, it is essential that all instructions given to drivers by signals are clear. The typical layout shown in Fig 34 should form the general basis of design for any new installation or modification of an existing layout. It will be seen that primary signals are sited on the near side of the approach close to the junction and the carriageway is marked with a stop line some feet in advance of the primary signal. Secondary signals giving the same signal indications are also required and these are normally sited on the offside of the road beyond the junction. Where refuges are provided, however, it is desirable to supplement the primary signal by means of a 'second primary signal' on the nearer end of the refuge and to site the secondary signal on the further refuge instead of on the offside of the road if by so doing it will be made more conspicuous to traffic. In this connection it is to be noted that the secondary signal must be sited within an angle bounded by the centre line of the carriageway extended through the junction and a line at 30° to the right of it, drawn from the intersection of the stop line near the centre line.

DIVISION OF CARRIAGEWAYS

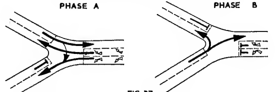


FIG 37

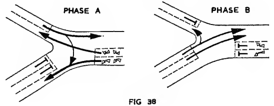


FIG 38

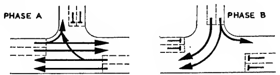


FIG 39

301. The typical layout may advantageously be modified to increase the width of approaches to better accommodate right turning traffic or the refuges off-set from the centre line for this purpose, provided the leaving side is not reduced below 18 ft on a four lane road.

302. Fig 35 shows the typical layout modified to provide a general widening of the intersection to obtain extra capacity of the order of 50% for the major road where little traffic is right turning; the increase in capacity may be even greater when the offside lanes are frequently obstructed by vehicles waiting to turn right.

303. Reasonable visibility splays are helpful in reducing accidents at signal-controlled junctions although a signal control may have to be provided where visibility is severely restricted.

Layout and Siting of Signals for Right Turning Traffic

304. A signal layout for a junction where right turning traffic is catered for by an early cut off phase (see paragraphs 321–322) is illustrated in Fig 36. In this example it is assumed that the traffic flow from approach B contains a heavy right turn and under such conditions the siting of secondary signals on roads with refuges may require special treatment, namely:

(a) The secondary signal for approach B (with associated green arrow – see below) may be sited on the central refuge in the opposite approach even if the siting is somewhat to the left of the centre line.

(b) The secondary signal for approach A is best sited on the far end of the refuge in approach A so that neither drivers turning right from A nor pedestrians crossing at A may be led to expect that the phase had terminated by seeing a red signal in the normal secondary position. A second primary signal in approach A is not usually needed in such circumstances.

The use of a right turn green arrow placed at the secondary signal (see secondary signal for approach B, Fig 36) where cut off phases are employed, is particularly valuable in both minimising delay to and increasing the safety of right turning traffic.

Division of Carriageways and Lane Marking

305. In many cases such as at 'Y' junctions, where the traffic divides fairly evenly to two forking roads, the centre line of the stem road may advantageously be off-set so as to allow more lanes into the junction; this is shown in Fig. 37.

306. In Fig. 38, the layout shown takes advantage of the three-lane width of the left forking road and so minimises the proportion of the cycle time required for Phase B.

307. Similarly, at a T junction the side entering from the stem of the T can advantageously be made one lane wider than on the leaving side (see Fig 39).

308. The arrangement nt any particular junction must, however, be decided from the traffic distribution and the respective carriageway widths.

309. The provision of lane lines and arrow marking at the approaches to traffic signals can be very beneficial in securing lane discipline and an orderly flow of traffic. The minimum width generally acceptable for traffic lanes at junctions in towns is 9 ft but in some instances particularly on roads containing a low proportion of heavy vehicles it may be satisfactory to mark lanes of lesser width.

310. Care is required when reserving particular traffic lanes exclusively for left or right turning traffic by means of arrows. Unless the volume of left turning traffic per lane is approximately equal to that on the remaining width of approach the capacity of the junction would be reduced by reserving one lane for turning traffic. Where a traffic signal filter arrow is provided the appropriate lane will require reserving for turning traffic.

311. With regard to reserving the off-side lane for right turning traffic this is best decided from site observation and if this lane is so frequently obstructed by traffic waiting to turn as to be of little value to accommodate straight ahead traffic then reservation would be advantageous.

312. The laning lines and arrow markings can often be advantageously extended further from the junction than the expected queue length: arrow markings can sometimes be advantageously supplemented by advance signs.

Width of Side Roads

313. Side roads often need a high proportion of the total cycle time to clear their traffic and it may be worth considering widening them so that they will require only a short phase of 15 to 20 seconds. This arrangement may increase the capacity of a main road by about 50% and is particularly useful where difficulties as to property preclude the widening of the main road.

Siting of Detectors

314. Vehicle actuated detectors are both used for registering demand for a particular phase and for extending the green and the siting is dependent upon the particular function required. In simple installations where they serve both to call and extend a phase they should be sited 130 ft in advance of the stop line where

speeds of 30 to 40 mph may be expected. Where conditions limit maximum speeds to less than 30 mph this distance may be reduced to 100–120 ft or even to 60 ft where the layout is such that speed at all times is very low. Detectors should cover an adequate width of road so that all vehicles including pedal cycles approaching the junction will actuate them. Detectors may also need to be sited within a junction to extend a special period for right turning traffic: some difficulties frequently arise in siting such detectors effectively and this is best carried out by observation on site to determine the track taken by right turning vehicles.

Controllers and Time Switches

315. Vehicle actuated signals cause less delay, particularly when traffic is light, than fixed-time signals. Fixed-time installations should be refitted as soon as possible with vehicle actuated equipment.

316. Modern vehicle actuated controllers have considerable flexibility to meet difficult traffic conditions; in particular they can be provided with means to vary the maximum green periods more closely to meet changes in traffic pattern throughout the day. This can be helpful for example where traffic on one phase is heavy at morning and light at evening peak, though the reduction in demand is not sufficient to effect an adequate reduction in the duration of its phase by relying solely on gap changes.

317. As an alternative, time switches may be added to existing equipment so as to change the settings of controllers to best meet peak conditions at different times of the day.

Limitations on Multiphase Systems

318. The general considerations as to the phasing of signals are discussed in paragraph 294(b) and the importance of keeping as much traffic as possible moving simultaneously was stressed. As lightly trafficked phases often seriously reduce capacity they should be eliminated where practicable: for example, where two phase control can be introduced instead of three phase control the capacity may be increased by about 50%. Sometimes due to possible danger from conflicting movements an extra phase may be needed but in general the aim should be towards the minimum number of phases.

319. With the continuing growth of traffic it is frequently advantageous to limit the number of phases to two in order to obtain the maximum capacity. This usually necessitates eliminating some conflicting movements and this may often be achieved in one of the following ways:

(a) Banning one or more right turning movements and diverting this traffic as described in paras 210–213. This may necessitate signal control at the junction to which this traffic has been diverted.

(b) Making one of the arms of the junction one-way away from the junction.

(c) Restricting the movement from one approach to either left or right turning only so that this movement can safely take place during one of the main phases.

(d) Closing one arm of the junction.

The resulting simpler control should give a greater measure of safety: drivers are better able to cope with the less complex traffic movements and where right turns are banned the crossing of approaches is made easier for pedestrians.

320. Two phase working can often be effected at complex junctions without the need to restrict traffic movements unduly, provided there is adequate space for separating points of major conflict. This is discussed further in paras 379–382.

Phasing for Turning Traffic

321. In the foregoing, methods have been discussed whereby phasing may be simplified by restrictive measures. Where, however, junctions are able to accommodate right turning traffic by providing extra facilities without causing congestion the following methods are available:

(a) Three phase control: Separate phases are provided for the approach containing the complement of right turning traffic and for the opposite approach. This system is applicable where:

(i) Roads are narrow and vehicles waiting to turn restrict other traffic.

(ii) The volume of right turning traffic is large and requires longer running time than its complement of straight ahead traffic.

(iii) Right turning traffic is heavy from both opposite approaches.

322. More frequently the traffic distribution met with contains one moderately heavy right turning movement and an 'early cut off' phase will then be more appropriate than a three phase system: delay will be reduced and capacity increased.

(b) Early Cut-Off: After the flow in both directions of a road has run for a certain period that in one direction is stopped to allow the other with its complement of right turning traffic to continue. (See para 304.)

(c) Late Start: The flow in one direction of a road is commenced some seconds before that in the opposing direction so as to permit some right turning traffic to clear the junction before the major flow in both directions takes place. The use of early cut phases are generally to be preferred to late starts on grounds of safety.

(d) Combined Late Start and Early Cut-Off:

(e) Extended Clearance Periods: See para 296.

Left Turning Traffic

323. Where the volume of left turning traffic justifies one lane being reserved exclusively for this traffic consideration should be given to the provision of a left filter signal (green arrow) in addition to the normal signals. The needs of pedestrians must also be borne in mind.

Pedestrian Phases

324. Where separate phases are provided for pedestrians as discussed in paras 408–410 it is essential that during the period when the 'Cross' signal appears the pedestrians may cross in safety and that when the 'Cross' signal is extinguished there is sufficient time for pedestrians to complete the crossing of roads before traffic reaches them. It is therefore necessary to allow for adequate all-red periods preceding and following the 'Cross' signal; it is generally preferable that the 'Cross' signal shall be relatively short (about 6 seconds) preceded for example by a 2 second all-red and followed by 4 seconds all-red: the actual periods are, of course, dependent upon road widths and layout. On wide roads it is desirable to increase the all-red following the 'Cross' signal. For pedestrian speeds in crossing a road see para 413.

Traffic Signal Calculations

325. The calculation of the capacity of any approach to a signal-controlled junction consists essentially of taking the maximum flow at which the approach would run if not impeded by signals (i.e. Saturation Flow), and reducing this in the ratio of effective green time (see para 334) to cycle time. The calculation of these factors is given below.

(a) Saturation Flow(s)

326. The saturation flow should normally be expressed in pcu's per hour (weightings for pcu values are given in para 54). Where there is no obstruction due to right turning traffic or standing vehicles on an approach or exit the saturation flow appropriate to peak-hour conditions may be taken as 1,600 pcu's/hr per 10 ft width and varying pro rata with the actual width in feet. For example, saturation flow for 22 ft width is 2·2×1,600 pcu's/hr. This relationship only applies to widths of over 17 ft and values for narrower approaches should be taken as follows:

w (feet)	10	11	12	13	14	15	16	17
s (pcu's per hour)	1,850	1,875	1,900	1,950	2,075	2,250	2,475	2,700

327. The above results apply to an average intersection. If the conditions are exceptionally good, i.e. on dual carriageways with no interference from pedestrians, good visibility and alignment and adequate turning radii and exit widths, the saturation flow should be increased by 20%. If the conditions are poor, i.e. with considerable interference from pedestrians, poor visibility or alignment, the saturation flow should be reduced by 15%.

328. Actual counts of saturation flow are generally preferable and these will include the effect of right turning vehicles, type of traffic and other local conditions. Where there are existing signals or the junction is police controlled it will be satisfactory to make such counts commencing, say, 5 seconds after traffic has started so as to eliminate starting delays and continuing the count until traffic begins to 'tail off'. After 10 to 20 counts it will usually be found that a reasonably consistent value of saturation flow is obtained.

329. Where saturation flows cannot be obtained from actual counts the value given above should be assumed and an allowance made for the effect of right turning vehicles. If the proportion of right turning vehicles is not large and causes little obstruction to other traffic the effect can be compensated for by making each right turning vehicle equal to one and three-quarters straight ahead vehicles. Thus, if the number of right turning vehicles is 'r' per hour the flow should be increased by ¾ r.

330. Where right turning vehicles obstruct the straight ahead flow it is generally satisfactory to calculate the saturation flow on the basis of a reduced width of approach. The reduction may vary from about 7 ft for light vehicles up to 9 ft where there is a high proportion (say over 20%) of heavy vehicles. Extended clearance time should be allowed for clearing the right turning vehicles held in the junction.

331. The effect of standing vehicles on the approaches to a junction on saturation flows may be estimated by reducing the effective carriageway width as follows:

$$\text{Effective loss of carriageway width} = 5{\cdot}5 - \frac{0{\cdot}9\,(z-25)}{g}\,\text{ft.}$$

Where g = green time for approach in seconds.
z = clear distance from nearest standing vehicle from the intersection to stop line.
If z is less than 25 ft put z = 25 ft.

NOTE: The expression should only be applied if it is positive in value.
The effective loss should be increased by 50% for a bus, lorry or wide van.

332. The effect of gradients on the approaches to traffic signals is that the saturation flow decreases by about 3% for every 1% of uphill gradient and increases by about 3% for every 1% of downhill gradient. This applies to gradients between 10% uphill and 5% downhill.

(b) 'y' Values

333. Taking each approach separately the ratio of flow to saturation flow is termed the 'y' value. As there is often more than one approach associated with a particular phase, the one with the maximum 'y' value is chosen to represent that phase. The sum of these maximum 'y' values for all of the phases is termed the Y value.

(c) Lost Time (L)

334. This is the total period during a cycle which is not effectively used for vehicular movement and consists of:

(i) the time when all signals are showing either red or red/amber to traffic and,

(ii) the time lost during each green and amber period due to traffic starting up or tailing off. This may vary but an average value of two seconds is usually satisfactory. Thus, effective green
= green + amber − 2 seconds
= green + one second.

On this basis the lost time on each change of phase under differing systems would be as follows:

(a) Controllers with 2-second red/amber periods

Staggered ambers (4 sec. intergreen)	3 seconds per phase change
Sequent ambers (5 sec. intergreen)	4 seconds per phase change
All-red of R secs	R + 4 seconds per phase change

(b) Controllers with 3 second red/amber periods (older patterns)

Concurrent ambers	2 seconds per phase change
Sequent ambers	5 seconds per phase change
All-red of R secs.	R + 5 seconds per phase change

The lost time per cycle (L seconds) will consist of the total loss for all changes of phase: for example for a two phase system with one 4 second intergreen and one 5 second intergreen, the total lost time would be 7 seconds.

(d) Cycle Time

335. The cycle time which gives the minimum overall delay is called the optimum cycle. Its value depends on the amount of 'lost' time in the cycle and on the ratio of flow to saturation flow on each approach.
The shortest cycle time, c_s, which will just pass all the traffic is given by

$$c_s = \frac{L}{1-Y} \text{ seconds}$$

When Y and L are as defined in paras 333 and 334. With this cycle time the intersection is 'fully loaded' all the time but the delays are excessively high.
An expression for the optimum cycle time, c_o, is given in Road Research Technical Paper No. 39 as

$$c_o = \frac{1{\cdot}5L+5}{1-Y} \text{ seconds}$$

336. It will usually be found that this cycle time is about twice as long as C_s. It is to be noted that although C_o gives the least delay, the delay is not greatly increased if the cycle time varies within the range 0·75 to 1·50 C_o. The cycle time will frequently be limited by local conditions (see para 340), but this does not usually cause the cycle time to lie outside this range.

337. Where the maximum cycle time is not restricted by such conditions it is generally considered that the upper limit (Cmax) should not exceed 120 seconds.

338. Whilst the maximum cycle time is required for calculating the Reserve Capacity for meeting future peak traffic volumes it will also be necessary to calculate the cycle time for existing peak volumes which should be within the range 0·75–1·50 C_o. For older equipment (generally installed before 1958) the maximum settings should be relatively short and to minimise the delay throughout the day the cycle time should be towards the lower limit of the range for peak-hour flows.

(e) Capacity

339. Methods of calculating Practical and Reserve Capacity are given below:

(a) *Practical capacity*. The capacity depends on the saturation flows, the lost time and the cycle time. Practical capacity may be taken as 90% of the flow which can just be accommodated in the maximum cycle, Cmax

Y takes the maximum possible value, Ymax say,

$$\text{where Ymax} = 1 - \frac{L}{\text{Cmax}}$$

If Yp is the Y value when the flow is 90% of the maximum possible, then

$$\mathrm{Yp} = 0{\cdot}9\ \mathrm{Ymax}$$

or
$$\mathrm{Yp} = 0{\cdot}9\left(1 - \frac{\mathrm{L}}{\mathrm{Cmax}}\right)$$

(b) *Reserve Capacity* (RC). The reserve capacity is the difference between the capacity and the flow. As a percentage of the present flow it is given by

$$\mathrm{RC} = \frac{0{\cdot}9\left(1 - \frac{\mathrm{L}}{\mathrm{Cmax}}\right) - \mathrm{Y}}{\mathrm{Y}} \times 100\% \qquad \text{(see Fig 40)}$$

or more conveniently $\mathrm{RC} = \left(\frac{0{\cdot}9\ \mathrm{Ymax}}{\mathrm{Y}} - 1\right) \times 100\%$

(c) *Approximate Calculation of Practical Capacity.* An approximate method, useful as a first step, particularly when designing complex installations, is to take for each phase the maximum flow per foot width and sum these for all phases. This sum can then be compared with a practical capacity taken as 130 pcu's/hr per foot. For example, at practical capacity the crossing streams could be in various proportions 65/65, 85/45, 100/30, etc so as to add up to 130. No allowance is made above for right turning traffic and appropriate reductions to carriageway widths should be made where required – see para 330.

(*f*) *Variation in Maximum Cycle Times*

340. The factors affecting the maximum practicable cycle time Cmax are:

1 The stop period should not be so long as to cause the queue of vehicles on an approach to a junction to exceed the available reservoir space frequently nor the cycle time so long as to cause the queue of right turning vehicles to exceed its own reservoir space.
2 The cycle time should not be so long that right turning vehicles cause congestion by interlocking.
3 Linked signals will generally require short cycles to allow reasonable progression.
4 Long cycles may have to be accepted when the lost time is high, e.g. multi-phase control.
5 In practice long cycle times may be needed to meet special conditions, e.g. on commuter or holiday routes, to ensure that side road green periods are fully utilised.

TRAFFIC SIGNAL CALCULATIONS
RESERVE CAPACITY DIAGRAM

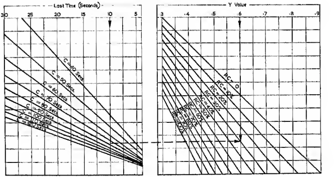


FIG 40

To calculate 'Reserve Capacity' use the left hand diagram to obtain a point corresponding to the 'Lost time' and the maximum cycle time suitable for the junction, extend a line horizontally from this point to the right hand diagram to meet a vertical line corresponding with the Y value – the Reserve Capacity (RC) may be read at the point of intersection.
Example: Lost Time 10 seconds; Cycle time 75 seconds; Y value ·6; *Reserve Capacity* 30%.

(g) 'y' Values for Early Cut-Off Phases

341. Where the control at a junction includes an early cut-off phase, the following method may be adopted to determine the 'y' values for the two stages.

342. (For the purpose of description it is assumed that the two stages are (1) northbound and southbound together and (2) northbound and right turning to east only.)

(a) Calculate the 'y' value for the southbound flow – let this be y_s.

(b) Calculate the 'y' value for the right turn from the south at the observed saturation flow for the turning lane or in the absence of observations a saturation flow of about 1,800 pcu's/hr may be assumed – let this 'y' value be y_r.

(c) Calculate the 'y' value for the straight ahead northbound flow based on a saturation flow for the approach width less, say, 9 ft (to allow for the width of vehicles waiting to turn or turning) – let this be y_n.

343. The 'y' value for the two stages taken together will then be y_s+y_r or y_n whichever is the greater. This value together with the 'y' value for the cross traffic will be used in calculating the cycle time and capacity. (The 'y' value for the 1st stage will be y_s and that for the 2nd stage will be y_r or y_n-y whichever is the greater. These will be required for calculating signal settings.)

344. The above method requires appropriate adjustment where right turning traffic occupies more than one traffic lane: in such conditions the saturation flow for right turning traffic is greatly affected by sharp turns or restricted carriageway widths and the value of determining saturation flows from site observations is stressed.

(h) Signal Settings

345. From the foregoing sections the 'y' values, cycle time and lost time will have been determined and it will be necessary to calculate the appropriate 'green' times for each phase.

346. It has been found that the least delay is obtained when the effective green time for each phase is proportional to the 'y' value for that phase. On the basis given in para 334 (ii) then for two phase control,

$$\frac{y_1}{y_2}=\frac{g_1+1}{g_2+1}$$

(where y_1 and y_2 are the y values for each phase and g_1 and g_2 are the corresponding green periods in seconds). As the sum of the effective green times $=C-L$:

$$g_1=\frac{y_1\,(C-L)}{y_1+y_2}-1 \text{ seconds}$$

$$g_2=\frac{y_2\,(C-L)}{y_1+y_2}-1 \text{ seconds}$$

347. These expressions can be extended for more than two phases.

348. It should be noted that as green periods of too brief a duration should be avoided, it may, in some instances, be necessary to lengthen the maximum settings to not less than 15 seconds to overcome this problem. Maximum settings should be sufficient to cater for traffic flows at any period of the day.

(i) 'Reservoir' Areas

349. In many junction designs areas of carriageway function as reservoirs for accommodating traffic making particular movements until released by a subsequent traffic phase. The actual area allotted per vehicle in such a 'reservoir' area is generally about 200 sq ft for each pcu. Where 'reservoirs' are large it may be necessary to start the 'green' early in order to clear a space for following traffic and an allowance of between 1 and 1½ seconds per 20 ft of reservoir length is usually sufficient for this purpose. (See Fig 51, such a reservoir area is marked LM thereon.)

350. It is often necessary to ensure that the reservoir areas are large enough to contain all vehicles likely to make a particular traffic movement, and as the number of such vehicles in each traffic cycle may vary considerably from the average number an allowance to meet such variations is desirable. In the table below line I gives the average number of vehicles arriving in each cycle: line II gives the corresponding numbers of vehicles which would not usually be exceeded more frequently than once in five cycles and line III gives the corresponding numbers that would not be exceeded more frequently than once in twenty cycles.

Line I	Average Number	2	4	6	8	10	12	14
Line II	Maximum number exceeded only once in five cycles	4	6	9	11	13	15	17
Line III	Maximum number exceeded only once in twenty cycles	5	8	11	14	16	18	20

351. The values given in line II would only be suitable for designs where no serious problems such as 'locking up' would result when the maximum number was exceeded.

Linking of Traffic Signals

352. Whilst a full appreciation of the advantages and disadvantages and of the application of various linking systems is beyond the scope of this memorandum the following information is given to assist when considering in principle the use of linked systems.

(a) Object of Linking

353. There are two general applications of linking, namely:

(a) To link signals where a group of closely associated junctions meet to form one traffic complex, so that the complex may function as a whole; the linking prevents obstruction caused by traffic queues at one junction interfering with the operation of adjoining junctions and also permits the major movements of traffic to pass through the system with little interruption.

(b) To link signals at junctions along a road and co-ordinate the green times at successive junctions so that traffic may flow progressively along the road with a minimum of delay – sometimes called the 'green wave' system.

(b) Methods of Linking

354. The two methods in most common use in this country are:

(a) Master controller linked Systems. With this method local vehicle actuated controllers are installed at each controlled junction and the operation of all local controllers is supervised by a master controller. The main functions of the master controller are:

(i) The cycle time of local controllers is determined by the master but this may be varied by means of time switches or traffic integrators (apparatus used to count traffic over selected periods). The usual arrangement is for cycle times to be lengthened when the traffic volume increases.

(ii) The local controllers are co-ordinated in operation by means of pre-determined 'plans' (three different plans may be operated with standard equipment so as to cover the peak periods and average conditions). These plans determine for each controller the times at which green periods are permitted to commence if called and their maximum duration.

A plan may include 'alternate' working, i.e. signals are alternatively red and green at successive junctions and 'block' working i.e. signals shall show the same colour at two or more successive junctions. It may also include displaced phases for favouring one direction of traffic. Plans for each period of the day should be designed to minimise the overall delay to traffic during the period of operation.

(iii) A feature of the master controller is that in order to prevent vehicle actuation bringing in green periods of too brief a duration at the end of the time allotted for the phase by the plan, restricted periods are imposed during which no vehicle actuated demand can be met. The result is that under light traffic conditions the local controllers are somewhat restricted in operation and the control may be less efficient than with no linking system.

(b) 'Tailor-made' linked systems without master controllers. This requires a choice to be made from the many different forms of linking available of those best suited to the traffic requirements of the controlled area. Generally speaking, one local controller will act as the key controller to the system and operate in a fully vehicle actuated manner, and will at the same time influence or control the operation of the remaining controllers in the linked system. Individual links may be arranged so that an event at the key intersection, e.g. a change of phase, or the passage of a vehicle, will influence or rigidly control the linked controller either immediately or after a pre-set time. This method is particularly appropriate to complex junctions which are beyond the capabilities of a single multi-phase controller and also to linked systems where one junction is the critical point of control of the whole system. The links may be modified or suppressed to suit light traffic conditions.

(c) Applications for Linking

355. Methods of linking signals along roads are given below:

(a) To One-Way Streets. The co-ordination of junctions along a one-way street is generally simple and efficient as each successive junction can be timed to allow progression for the through route at any appropriate speed, which may be varied by time switches or integrators. Control is usually carried out by a master and local controllers but a fixed time system may be operated satisfactorily in some cases.

(b) To Two-Way Streets. The major problems of linking arise in the application to two-way streets as the system must be satisfactory for traffic streams in each direction. Ideally, the spacing of junctions should be about 300 yards to provide a progressive speed of about 20–25 miles per hour in each direction. When replanning an urban area where junctions are to be signal-controlled it is important

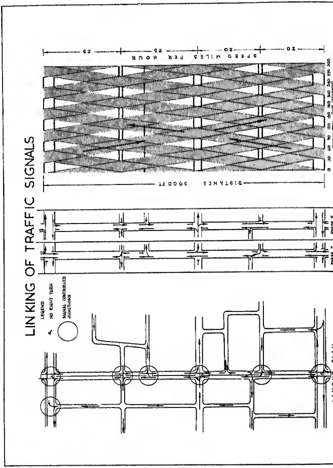

LINKING OF TRAFFIC SIGNALS

FIG 41

to keep this spacing in mind. In most cases unsatisfactory spacing of junctions necessitates some compromise in the signal plan, but much can usually be achieved by subordinating the operation of side roads to that of the main road either by timing or restrictive measures so as to obtain a reasonable progression on the through route. To prepare such a scheme it is necessary to work out a time-distance diagram, an example of which is shown in Fig 41. Traffic diagrams must also be prepared so that the proportion of running time required at different periods of the day at each junction can be calculated. Much trial and error is needed to achieve the most satisfactory plans. Where there are distinct changes in distribution at peak times such as on radial routes, it is often advantageous to have a progressive plan which favours the heavier traffic movement at such times. In preparing the time distance diagram it is important to ensure that the capacity of each individual junction is adequate for the expected traffic volumes.

356. An example of the application of linking to a typical two-way urban route is shown in Fig 41. Some minor roads have been made one-way and certain right turns banned in order to achieve two phase working for the signals along the main road. The scheme thereby provides high capacity and delays to traffic will be small. For the sake of clarity the arrangement shown is over-simplified as the side road running times would not necessarily be equal throughout the system.

(*d*) *Use of Computers*

357. Many bodies throughout the world are investigating the value of using computers for co-ordinating the operation of local controllers throughout the area of a town. Already the advantages of computer control over fixed time progressive systems have been demonstrated in Canada and the USA. Considerable research is still needed to determine whether computer control can offer worthwhile advantages over the vehicle actuated progressive systems already available in this country.

The Roundabout

General

358. The design of roundabouts has made substantial advances during the past few years and it is now possible to estimate closely the traffic capacity of any proposed design.

359. The circumstances where roundabouts form the appropriate method of controlling an intersection are largely dependent upon the layout of the site, the proportion of right turning traffic and the traffic characteristics of the route: for instance roundabouts are, on the whole, more satisfactory than traffic signals on roads where speed is not restricted. These aspects are considered in greater detail in para 446.

360. It is to be noted that roundabouts when overloaded are likely to 'lock up' and do not readily recommence functioning. It is therefore necessary to design them with adequate extra capacity to meet this contingency.

Layout of Roundabouts

361. Roundabouts require to be individually designed to suit the site, volume and distribution of traffic. The design should aim at providing an adequate margin for the growth of traffic and in consequence should, where possible, be on the generous side. Large roundabouts not only provide additional traffic capacity but also are conducive to the smooth flow of traffic and reduce the possibility of 'locking up' due to sudden fluctuations in flow.

362. The overall size of a roundabout is largely dependent on the weaving lengths (l), see Fig 42. To achieve smoothness of flow the radius of curves at entry (R1) should usually be between 40 and 75 ft; the smaller dimensions being used on short weaving lengths or where greater radii are not practicable. It is desirable to give dominance to the flow on the roundabout and for this purpose the radii on the central island (R2) should preferably be greater than the entry radii. Exit radii (R3) should generally be large, a tangential alignment being the best in some circumstances (see exit A Fig 42). Where, however, pedestrian flows are important or pedestrian crossings are provided, radii of about 40 to 60 ft may be desirable to keep speeds of exit low.

363. The layout should avoid as far as possible large exit angles, obtuse internal angles around the roundabouts (see Fig 42) or straight 'run ins' but where these are unavoidable deductions from capacity should be made as outlined in the following sections.

364. For safety reasons large weaving angles should be avoided.

365. It will usually be necessary to prepare a number of draft layouts and calculate for each of them the capacity of each weaving section, making modifications to the layout until the desired capacity is obtained.

366. The designer should not be wedded to geometrical or symmetrical shapes, such as a circle, for the central island if the layout and angles of approach roads are irregular. Asymmetric shapes either wholly curved or a combination of straights and curves, as illustrated in

Fig 42 will often provide the only satisfactory solution. The dead areas to be seen on the periphery of many roundabouts are often an indication of poor design.

367. Special considerations apply to the layout of roundabouts with grade separation where the size of such roundabouts and layout is governed by the associated structures and may lead to high operating speeds.

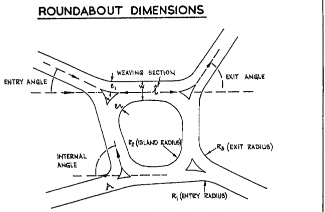


FIG 42

Design Calculations

368. In order to design the roundabout with the necessary traffic capacity to meet the future growth of traffic a comprehensive traffic census should be taken for both morning and evening peak conditions (or sometimes at other times where conditions are abnormal). A diagram is then prepared showing the volume and proportion of weaving traffic on each weaving section of the roundabout for each peak period, these volumes being given in pcu's, using 'roundabout' weightings (see paras 54 and 147). From this diagram the proportions of weaving traffic can be read off and in conjunction with the weaving widths, entry widths and weaving lengths taken from the draft design applied either to the formula below or to the Roundabout Design Chart, Fig 43, to find the practical capacity of each weaving section of the roundabout.

$$Qp = \frac{86w\left(1+\frac{e}{w}\right)\left(1-\frac{p}{3}\right)}{1+\frac{w}{l}}$$

where Qp = practical capacity of weaving section of roundabout

w = width of weaving section in feet

e = the average width in feet of the two entry widths (i.e. from an approach 'e_1' and within the roundabout 'e_2')

l = the length of weaving section between ends of guide islands

p = proportion of weaving traffic, i.e. ratio of sum of crossing streams to the total traffic on that weaving section.

Fig 42 shows the lengths and widths referred to.

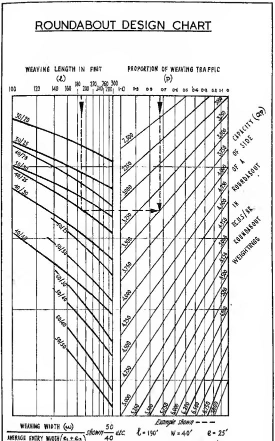
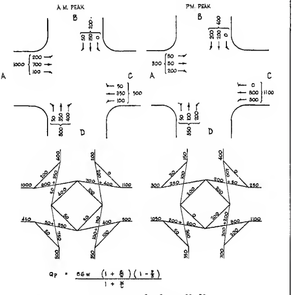


FIG 43

To determine the capacity of the side of a roundabout use the left hand diagram to obtain the point corresponding to the weaving length, weaving width and average entry width (interpolating where necessary) extend a line horizontally to the right hand diagram from which the capacity is given for the proportion of weaving traffic.

To determine the dimensions of a side of a roundabout use the right hand diagram to obtain a point corresponding to capacity and proportion of weaving traffic, and draw a line horizontally to the left hand diagram. This line will cut various alternatives of weaving length, weaving width, and entry widths from which a suitable design may be obtained.

ROUNDABOUT CALCULATIONS



$$Q_P = \frac{86w\left(1 + \frac{e}{w}\right)\left(1 - \frac{p}{3}\right)}{1 + \frac{w}{l}}$$

VALUES ASSUMED IN DESIGN

$$\begin{cases} e = \frac{e_1 + e_2}{2} = \frac{36 + 20}{2} = 28 \text{ FEET} \\ W = 50 \text{ FEET} \\ l = \text{AS IN THE TABLE BELOW} \end{cases}$$

DIMENSIONS				A.M. PEAK					P.M. PEAK				
SIDE	l	W/l	e/W	FLOW	P	$1-P/3$	Qp	RESERVE CAPACITY	FLOW	P	$1-P/3$	Qp	RESERVE CAPACITY
A B	140	·36	·56	1800	·67	·78	3700	105% +	600	·58	·81	4000	570%
B C	135	·37	·56	1400	·93	·69	3400	143%	850	·77	·74	3600	320%
C D	130	·38	·56	800	·81	·73	3500	340%	1700	·71	·76	3700	117% ⊕
D A	150	·33	·56	1250	·92	·69	3500	180%	1350	·97	·68	3400	150%

+ MINIMUM RESERVE CAPACITY AT A.M. PEAK 105%
⊕ MINIMUM RESERVE CAPACITY AT P.M. PEAK 117%

FIG 44

369. Comparisons can then be made of the flow (in pcu's) with the capacity provided (in pcu's) for each weaving section of the roundabout for each peak period. Fig 44 shows an example of roundabout calculations.

370. The formula given above is based on 80% of the maximum possible flows on a single weaving section so as to provide a margin to meet the effects of wet weather, possible interaction between weaving sections, variations in flow over the hour and pedestrian influence. The formula is valid under the following conditions:

1. There are no standing vehicles on the approaches to the roundabout.

2. The site of the roundabout is level and approach gradients do not exceed 1 in 25.

3. As the formula was obtained under experimental conditions (though it has since been well tried under road conditions) the ranges of variables given below should be noted: some variation beyond the ranges given has generally been found satisfactory.

w (weaving width)	20–60 ft
$\frac{e}{w}\left(\frac{\text{average entry width}}{\text{weaving width}}\right)$	0·4–1·0
$\frac{w}{l}\left(\frac{\text{weaving width}}{\text{weaving length}}\right)$	0·12–0·40
p (proportion of weaving traffic)	0·4–1·0
l (weaving length)	60–300 ft

371. Where the layout is not conducive to uniform speeds or where the capacity is affected by pedestrian flows the following arbitrary adjustments to capacity may be made.

1. (a) Where the entry angle is between 0 and 15° deduct 5% from the capacity of the weaving section.
   (b) Where the entry angle is between 15 and 30° deduct 2½% from the capacity of the weaving section.
   (c) Where the exit angle is between 60 and 75° deduct 2½% from the capacity of the weaving section.
   (d) Where the exit angle is greater than 75° deduct 5% from the capacity of the weaving section.
   (e) Where the internal angle is greater than 95° deduct 5% from the capacity of the weaving section.

(The angles referred to are those between extensions of the centre line of the weaving section and that of the approach or exit roads or the weaving section as appropriate – see Fig 42.)

F*

2. Where the pedestrian flow exceeds 300 per hour across the exit from the roundabout an arbitrary reduction of one-sixth should be made in the practical capacity of the preceding weaving section.

Limits of Capacity for Roundabouts

372. Experience has not yet indicated a limitation on the volume of traffic which can be accommodated by a roundabout provided that it is designed correctly. In this country weaving sections of roundabouts are known taking over 6,000 pcu's per hour of which over 70% is weaving. However, driving conditions become arduous when high traffic intensities are reached. It is preferable to consider grade separation when weaving volumes would exceed 3,500 pcu's per hour.

Delay on Roundabouts

373. The time lost in negotiating a roundabout has been found from a limited number of observations to be the sum of the following:

1. The difference in journey time in traversing the roundabout at, say, 15 mph (on large roundabouts 20 mph may be more appropriate) and that required for passing in a straight line across the roundabout at the normal running speed of the road; and

2. $\frac{450}{25+RC}$ seconds, where RC is the reserve capacity (per cent) of the most saturated weaving section. This delay should be applied to any movement crossing a roundabout. (This formula does not apply when the practical capacity is exceeded.)

Traffic Signs for Roundabouts

374. Advance direction signs and flag type exit signs require special attention so that drivers may take up positions quickly and correctly from which to weave and may know precisely the exit by which they should leave the roundabout.

Review of Existing Roundabouts

375. Flow conditions at many existing roundabouts could be improved and their capacities increased by minor amendments to layouts, kerb alignment, etc.

376. There are many older roundabouts where exit radii, the radii on the corners of the central island, weaving widths, and in some cases even the entry radii are too small. Site observations both when the roundabout is running free and when near maximum capacity should indicate what is required in the way of kerb realignment or other adjustments.

CHANNELISED AND COMPLEX JUNCTIONS

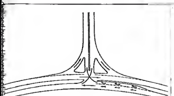


FIG 45

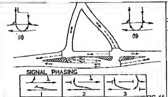


FIG 46

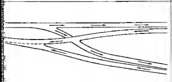


FIG 47

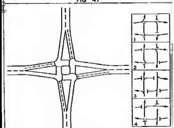


FIG 48

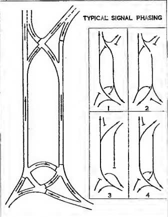


FIG 49

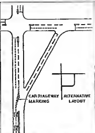


FIG 50

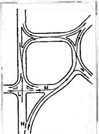


FIG 51

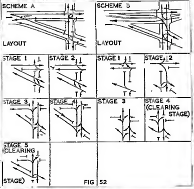


FIG 52

377. Attention should be paid to the background presented by the central island to approaching drivers. Shrubs, vertical railings and similar features can cause the central island to be extremely poorly defined, especially at night, both for lighted and unlighted sites.

378. Structures on the central island, e.g. bridge parapets, where a railway passes beneath a roundabout can also be misleading if the shape of the structure does not conform with that of the central island. In such cases the edge of the island should be clearly defined by marker posts, horizontal bars or light coloured mesh panels which ought ideally to be continuous around the island.

Channelised and Complex Junctions

379. Although the principle of 'channelisation' has long been employed in the design of junctions, the term has in recent years been used to describe the principle of separating and guiding traffic streams through defined channels usually formed by traffic islands. The advantages of a satisfactory layout of this type are:

(a) Drivers are, at any one time faced with simple decisions as to choice of movement: delay and accidents caused by indecisions are thereby reduced.

(b) The paths taken by vehicles are closely defined so that each driver finds the movements of other drivers more predictable. This results in greater safety.

(c) The separation of traffic streams reduces the volume of conflicting movements at any one point so that the capacity of the junction may often be improved.

(d) The 'channels' are aligned so as to follow as far as possible the natural vehicular paths: this improves the smoothness of operation of a junction and makes it readily understood by drivers.

(e) The layout is designed to suit the traffic pattern, e.g. principle movements are given the easiest paths, areas of carriageway are provided for vehicles waiting to cut across other traffic streams and curves are provided for slowing down vehicles into stopping positions.

380. These principles are, of course, applicable to both uncontrolled and signal-controlled junctions: the use of signal control is dependent upon the volume of traffic at points of conflict (see paras 281–284). In applying these principles it would not usually be practicable (or necessary) to separate all traffic movements into defined channels, particularly if in so doing the traffic islands became too small.

381. Fully channelised designs may require too large an area for application to roads in town centres. Even in these cases, however, it may be found that complex junctions can be simplified by applying channelising principles, so that two phase signal control can be applied at each conflict point.

382. The application of some of the principles referred to above is shown in Figs 45–52.

Figure 45: In this design for a three-way junction all traffic movements are provided with separate channels – a particular feature is the waiting area provided for vehicles making a right turn from the major road.

Figure 46: This design shows the principle of arranging for traffic to flow into and out of a minor road at the same time. This results in higher capacity than by a simple three phase system. It can be applied also to one-way street systems (see inset diagrams (a) and (b)).

Figure 47: In this example the layout is designed so that traffic which has to cut a major stream is slowed down by a curve to the stopped position from which drivers are well positioned to see the traffic stream which must be crossed.

Figure 48: The feature of this signal-controlled design is the method by which right turning traffic is positioned in front of the traffic which moves in the succeeding traffic phase. The area provided for right turning traffic requires to be large enough to hold the probable number of right turning vehicles per phase (see paras 349–351).

Figure 49: This example shows how a complex street pattern can be resolved into a system of simple two phase movements, 'progressively' linked in association with one-way movements.

Figure 50: The feature of this design is the diversion of right turning traffic before a major junction is reached. Although additional signal control is usually needed the capacity can be greatly improved when dealing with a heavy right turn.

Figure 51: Often site conditions prevent a complete roundabout being constructed and one traffic cut has to be controlled by signals. In such a design the slip road MN should be sited so that the length of road LM is adequate to accommodate the probable number of vehicles arriving when the signals are 'at red'.

Figure 52: In this example alternative methods of operating a 5-way junction are shown. In Scheme A control at each intersection is basically two phase whilst in Scheme B there are three main phases. It will be found that the capacity of the former is usually substantially greater.

Graded Separated Crossings

General

383. When designing schemes to meet the future traffic requirements in the larger urban areas it will often be

found that surface level designs will be incapable of providing the necessary traffic capacity and that grade separation of the major traffic movements will be needed. liminary designs and then select those most suited for more detailed examination. A suitable ground level scheme should also be included in the final 'short list' where this is a practicable alternative.

FLOW DIAGRAM FOR GRADE SEPARATION SCHEMES

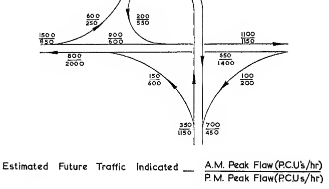

600/250
200/550
1500/850
900/600
1100/1150
800/2000
650/1400
150/600
100/200
350/1150
700/450
Estimated Future Traffic Indicated — A.M. Peak Flow (P.C.U's/hr) / P.M. Peak Flow (P.C.U's/hr)

FIG 53

384. Owing to the high cost of construction and permanence of a scheme involving flyovers or underpasses it is particularly important before considering layout designs to obtain the best possible estimate of future peak-hour flows and distribution.

385. In view of the many possible types of grade separation schemes ranging from simple grade separation for one stream of traffic only to full interchanges, it is essential at the initial stage to prepare several preliminary designs and then select those most suited for more detailed examination.

386. The justification for adopting grade separation is largely determined by the following:

(a) A ground level scheme of sufficient capacity is not practical.

(b) The scheme is justified economically from the saving in delay to traffic and accidents.

(c) Grade separation is cheaper on account of topography or on grounds that expensive sites can be avoided by such a layout.

(d) Roads cross urban motorways.

387. The selection of the most appropriate designs from the alternative schemes is obtained by comparing the traffic capacities, operational characteristics (safety, easy comprehension by drivers, etc), costs including land costs, and relative economic benefits (i.e. rate of economic return), and maintenance of traffic during construction.

388. Each proposed design should show clearly the estimated flow and distribution for each peak hour and they can be conveniently shown as in Fig 53.

389. Whilst it is outside the scope of this bulletin to consider geometric design, it will, however, be necessary to assess the capacity of the various roads and junctions comprising grade separated schemes and some notes are given below. In many schemes involving simple flyovers or underpasses, ground level treatment will consist of roundabouts or traffic signal-controlled junctions and their design and capacity have already been dealt with in paragraphs 294–382.

Flyovers and Underpasses

390. The maximum capacity may be based on 1,500 pcu's/hr (Urban Road Units – see para 54) for each traffic lane of 11 or 12 ft in width. Where lane widths of only 10 ft are obtainable the capacity should be reduced by 10%.

Slip Roads (including loops and ramps)

391. As gradients and curvatures are usually more unfavourable on slip roads than elsewhere, a basic capacity of 1,200 pcu's/hr per lane of 11 or 12 ft is appropriate. For single lane one-way roads or for two-lane two-way roads, where the volume for both directions exceeds 1,200 pcu's/hr extra width should be provided to allow both for curvature and for passing any vehicle which may be stalled or broken down. On two-way roads carrying less than 1,200 pcu's/hr extra width for passing a stationary vehicle is not necessary.

Merging of Traffic from Slip Roads with Major Road

392. As the volume of traffic from a slip road which may safely merge with the major road traffic depends on the volume on the major road, a detailed analysis of flows at each peak period is required.

393. It is not sufficient to assume that the volume of the two merging streams of traffic will equal the capacity of the major road beyond the junction: this is due to the screening effect of traffic on the nearside lane which prevents traffic from the slip road filling the traffic gaps in the offside or middle lanes. Consequently, the slip road volume cannot exceed the capacity of the gaps in the nearside streams unless an extra lane is provided on the nearside of the major road. In urban conditions the capacity of the nearside lane in the area of the merging flows can be taken as 1,200 pcu's/hr where an acceleration lane is provided: the maximum input for the slip road is then 1,200 – q pcu's/hr where q is the flow in the nearside lane before the junction.

394. There is some difficulty in determining 'q' as the distribution of traffic between lanes depends not only on the volume of traffic but also on the tendency of traffic to shift from the nearside lane in the vicinity of junctions. There is little experience in this country on which to make a close assessment of the traffic distribution near junctions but experience in the USA shows that on the approach to a junction the nearside lane usually carries about 600 pcu's/hr less than the offside lane within the range 800–2,400 pcu's/hr on the carriageway in one direction. As the total flow on the main road (Q) will be known as from the above we can say that $q = \frac{Q}{2} - 300$ then the maximum flow from the slip road $(1{,}200 - q)$ can be taken as $1{,}500 - \frac{Q}{2}$ pcu's/hr. This expression applies to a dual 2-lane carriageway where an acceleration lane is provided.

395. Where these flows are exceeded it will be necessary to consider providing an additional lane to the main road.

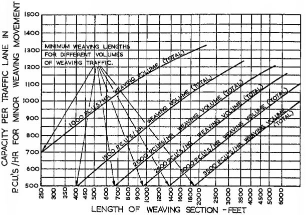
Exit from Major Road

396. The capacity of a single lane exit may be taken as about 1,200 pcu's/hr provided the deceleration lane is well designed and sign posting gives adequate warning well in advance of the junction.

Weaving between Loop Junctions (or Slip Roads)

397. In most forms of interchange the exit from the major road is in advance of the entry thereto and consequently no weaving manoeuvre occurs between them. Where the position of these junctions is reversed as between loops in a cloverleaf design, weaving takes place between them. In most designs the length between loops (or other junctions) is adequate for weaving volumes up to about 1,500 pcu's/hr provided an extra traffic lane is added. For larger weaving volumes the length between the loops may need to be increased beyond that necessary for the geometric layout. The minimum weaving lengths for different volumes of total

CAPACITY OF LONG WEAVING SECTIONS OF ROADS AT 35-40MPH OPERATING THROUGH SPEED



EXAMPLE:- LENGTH BETWEEN JUNCTIONS 1000 FEET, NON WEAVING TRAFFIC 1700 P.C.U'S/HR, MAJOR WEAVING TRAFFIC 1450 P.C.U'S/HR, MINOR WEAVING TRAFFIC 550 P.C.U'S/HR FROM DIAGRAM FOR TOTAL WEAVING VOLUME 1450+550 = 2000 P.C.U'S / HR AND WEAVING LENGTH 1,000 FEET, CAPACITY PER LANE FOR MINOR WEAVING MOVEMENT = 650 P.C.U.'S/HR PER LANE.

∴ WIDTH OF WEAVING SECTION = $\frac{1700 + 1450}{1500} + \frac{550}{650}$ =

2·95 I.E. 3 TRAFFIC LANES.

NOTE: IF WEAVING LENGTH HAD BEEN THE MINIMUM VIZ. 660 FEET 4 TRAFFIC LANES WOULD HAVE BEEN REQUIRED.

FIG 54

weaving traffic are shown in Fig 54,* these values apply only to roads (including urban motorways) where operating through speeds up to 35–40 mph apply. As an alternative to increasing the weaving length, the weaving manoeuvres can be diverted to a subsidiary road, parallel with the main road, where weaving can take place at slower speeds: this road only needs to be about half as long as the weaving length that would be needed on the main road. This subsidiary road, often called a collector-distributor road, can be connected between the loops of a cloverleaf and to the main road by junctions in the normal sequence (i.e. exit precedes entrance junction).

398. Where the weaving length provided is the minimum as shown in Fig 54, the width of the weaving section (of either the main road or the collector-distributor road) can be calculated by allowing a capacity of 1,500 pcu's/hr per traffic lane for the total of the non-weaving and the major weaving traffic movement and a capacity of 500 pcu's/hr per traffic lane for the minor weaving movement. Where, however, the actual weaving length is greater than the minimum it is permissible to allow a higher traffic capacity for the minor weaving traffic movement as shown in Fig 54. Where a non-weaving movement exceeds 600 pcu's/hr it is generally advisable to allow a separate lane for it: the remaining width is calculated with this volume excluded.

Traffic Safety Measures

Accidents

399. This section covers some aspects relating to safety not covered in earlier sections. Some general indication of the effect on safety of measures already considered may be obtained from the following statistics:

Table 8

Description of Change	Reduction in personal injury accidents found in sample studies
1 Staggering of cross roads	60%†
2 Application of No Waiting Regulations	up to 30%
3 Improvement of road alignment at bends	80%†
4 Provision of dual carriageways	30%†
5 Improved visibility at junctions	30%†
6 Provision of traffic signals	40%
7 Provision of roundabouts	50%

† These reductions were found in rural areas

400. In formulating measures to reduce accidents at a particular site it is necessary to study each accident in detail to ascribe the contributing factors. Accident records covering as long a period as possible are desirable particularly when accidents are few. Attention should be directed to any factors common to a number of accidents. Whilst there are necessarily many accidents arising from human error, poor road conditions such as restricted visibility, lack of traffic control, etc, can result in the indecision which is often a contributory cause.

401. When considering accidents along a particular road it may be desirable to compare the accident record with that obtaining in similar conditions elsewhere and this is best carried out by calculating the number of personal injury accidents per million vehicle miles $\frac{3{,}000\,\mathrm{n}}{\mathrm{VL}}$ approx. where 'n' is the number of personal injury accidents per year, 'V' the average number of vehicles per day and 'L' the length of road under review in miles. Typical values for personal injury in Great Britain are given in Table 9.

Table 9: Personal-injury accidents per million vehicle miles

Typical road and Development	Accidents per million vehicle-miles
Shopping centres	8–20
Residential	4–7
Roads not built up but with much rural traffic	4–7
Dual carriageways – rural (de-restricted)	1·6
County roads	1·5–2·5
Motorways	0·6
3 lane rural (de-restricted)	1·6
3 lane urban (de-restricted)	2·8

Pedestrian Facilities

402. The crossing of minor roads usually causes no difficulty to pedestrians who are able to cross after waiting no more than a few seconds for an adequate gap in traffic to occur. Pedestrians can generally cross in quite short traffic gaps, usually of the order of 7 seconds or less, and as traffic streams flow in approximate random distribution the delay in waiting for a suitable gap can be calculated from the traffic volume.

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* The information shown in Fig 54 and some of that contained in paras 407 and 408 has been derived from experience in the USA – see O.K. Normann – Operation of Weaving Areas, Highway Research Road Bulletin No. 167, 1957.

403. Delays in waiting for a gap are quite small until considerable volumes are reached and Fig 55 shows the delay/traffic volume relationship.

404. When traffic volumes are heavy, the situation can be considerably eased by the provision of a refuge which by dividing the traffic streams reduces the flow to be crossed at one time and so reduces total delay; the saving in time can be calculated from the diagram. Unfortunately carriageway widths are often narrower than the 40 ft needed to accommodate a refuge safely but in many cases where other measures are inappropriate it may be found that a local widening of the carriageway and the provision of a refuge is the best solution.

405. Experience has shown the value of refuges in reducing accidents to pedestrians: the risk to a pedestrian at a pedestrian crossing without a refuge is 50% higher than at one with a refuge.

406. Where there are concentrated pedestrian movements throughout the day and delay is unreasonably high then an uncontrolled pedestrian crossing should be provided. Reference should be made to the various circulars on this subject in particular to the Circular 668 of the 19th June, 1951, which gives guidance in Appendix III as to the selection and siting of uncontrolled pedestrian crossing places.

407. Whilst the risk at a pedestrian crossing is less than half that on the road generally, the risk within 50 yards

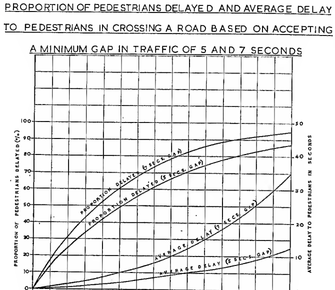

FIG 55

of a crossing is about twice as high as on the rest of the road. At the same time the safest crossings are those most heavily used. Hence it is important to site crossings so that they will be as attractive as possible to the greatest number of pedestrians, thus minimising the numbers crossing elsewhere, and also ensuring maximum constant use of the crossing.

408. A further measure to consider is the provision of traffic signal-controlled crossings. These may take the form of a separate signalled installation for pedestrians, preferably linked with other traffic signals along a route, or of part of the signalling equipment at a road junction. In linked installations the operation of the crossing should be so arranged that it favours the pedestrian at the time when the traffic flow on the road is least. Suitable arrangements can be made quite near an intersection. The pedestrian crossing is operated (on demand) some seconds after red has appeared at the intersection to the road on which the crossing is sited. The 'cross' is terminated some seconds before traffic is released. With this arrangement the pedestrian signals do not interfere with the intersection or reduce its capacity. Such crossings should be sited sufficiently far from an intersection to avoid any possible confusion from two sets of signals in close proximity: a distance of about 100 yards is usually sufficient for this purpose.

409. Another method of providing pedestrian phases at heavily trafficked junctions where a separate pedestrian phase would cause congestion is sometimes called the 'walk with traffic' system. In this system pedestrians cross in paths parallel to the traffic streams running on vertical filter arrows during the first part of one or both phases. The second part of the phases consists of a full green signal permitting traffic to turn and with the pedestrian phase extinguished. Before the appearance of the 'cross' signal for pedestrians a clearance period is needed but in order to give adequate clearance after the 'cross' signals, so that pedestrians may complete the crossing in safety, stop lines and pedestrian crossing should be set back further from the junction than normally. This system is not suitable for narrow roads as separate traffic lanes are needed for turning and straight ahead traffic.

410. There are considerable disadvantages in providing pedestrian phases at important intersections as the pedestrian phase must be sufficiently long to ensure that it is completely safe for the pedestrian to cross (see para 324). The consequent reduction of time available for other traffic movements often necessitates substantial lengthening of the cycle time with the result that pedestrians do not wait for the period allotted to them and cross during traffic phases. Frequently the solution to the problem is to provide a clearing period so that pedestrians may complete the crossing of half the road under some protection from the signals. At complex junctions it is often possible to provide lengthy phases for pedestrians without affecting traffic capacity and this should be done in all such circumstances.

411. Clearly pedestrian subways or foot-bridges provide the most satisfactory means of crossing roads and on fast roads where misjudgment of traffic gaps tends to occur or on roads carrying high volumes of traffic such measures should be considered. The provision of subways or bridges should also be considered at large roundabout systems where the traffic concentration is so high as to afford few breaks for pedestrians.

412. Some difficulty occurs in ensuring full usage of pedestrian subways or bridges, and it is desirable (a) to take a survey of local pedestrian movements, (b) to site the bridge or subway in the position best suited and (c) to ensure that by means of guard rails or location of footways, etc, the time taken by pedestrians to use the bridge or subway is not greater than by crossing on the surface.

413. The delay to pedestrians crossing the road can be obtained by the method given in para 123 or estimated from Fig 55, it is usual to take speeds of walking on the level at 5 ft per second, slopes 4 to 4½ ft per second and at half foot per second vertically on stairs.

414. Subways offer about half the rise and fall as compared with bridges, and are generally to be preferred. It is usually desirable to provide ramps at about 1 in 10 gradient so as to assist those who are crippled or with perambulators and additional stairways are often an advantage to give access to other directions not catered for by the ramps.

415. Where pedestrian movements are heavy, such as at railway stations, care is needed to ensure that the minimum width of subway (usually 7 ft 6 in) is sufficient and for peak flows it is considered that a maximum flow of 27 persons per minute per foot of width is appropriate for corridors and 19 persons per minute per foot width for stairs. Where display windows are sited in subways it is usual to allow an extra width of about 2 ft 6 in at each side where these are provided.

416. The capacity of open footways may be taken as 20–30 persons per minute per two foot width of pavement after deducting approximately 3 ft in shopping areas and 1 ft 6 in elsewhere.

Pedestrian Guard Rails

417. Accidents can often be prevented by the use of guard rails and these are generally placed either (a) in short lengths opposite exits from schools, recreation grounds, footpaths or passages in order to prevent children running heedlessly into carriageways and (b) along roads to lead pedestrians to use subways or crossing points. A particularly valuable use is to lead pedestrians at signal-controlled junctions to the safest crossing points.

Speed Limits

418. In general the scope for further introduction of 30 mph speed limits in most towns is very limited. An important measure which is now available is the 40 mph speed limit which can be used either to raise a limit previously fixed at 30 mph or by applying it to a road at present unrestricted. For advice on changes in speed limits reference should be made to the Summary of Advice attached to Circular 796 of 29th December 1961 and the Report of the Departmental Road Safety Committee on the Experimental Introduction of 40 mph Speed Limits in London Traffic Area.

419. Where accidents occur in localised areas it is preferable to consider measures to improve the layout rather than apply a speed limit and a detailed examination of accidents occurring will in many cases indicate the appropriate remedy to the situation.

420. The introduction of a 40 mph speed limit or the reduction from 40 mph to a 30 mph tends to discourage drivers from using a particular route. This may have repercussions where speed limits are applied to by-passes: a restriction on such roads may well cause some through traffic to avoid the by-pass and revert to routes through the town area with consequent adverse effects upon the accident record in the town.

Sight Lines at Junctions

421. The visibility from the minor road at an uncontrolled junction requires to be sufficient for a driver to judge when a gap occurs which is adequate for him to cross the streams of traffic on the major road. For urban conditions most drivers will accept for this manoeuvre a gap of about 7 seconds and accordingly the sight line requires to be about 300–350 ft for a speed of 30 mph on the major road. Faster roads require correspondingly greater visibility.

422. The distance up a minor road from which this visibility should be provided is dependent on several factors, for example:

(a) The normal standard for rural areas of 50 ft, although desirable, is not so important on busy urban roads owing to the infrequency of gaps long enough to allow the driver to enter the major road without stopping or slowing down appreciably.

(b) Visibility from a distance of 20–30 ft from the major road improves the capacity of the side road by enabling two or three vehicles to enter the major road when adequate gaps occur.

(c) A visibility distance which allows a rolling approach, say 15 to 20 ft, provides for greater safety than one which necessitates a stop.

(d) In the case of a lightly used vehicular access there should always be adequate visibility from the stop position.

423. In consequence of these factors the distance up the minor road from which 300–350 ft visibility should be obtained would normally be 30 ft for through minor roads, 20 ft for cul-de-sacs or important private accesses and between 10 and 20 ft for less important accesses (7 ft is approximately the distance from front of car to the driver). These visibility distances should be obtainable both in the vertical and horizontal planes: it is generally assumed that a driver's eye level is 3 ft 6 in.

Staggering of Junctions

424. At uncontrolled crossroads vehicles should, if possible, be prevented from making a direct crossing by staggering. In cases where a crossroads has been converted to a right-left stagger the reduction in accidents has amounted to 60%. Where left-right staggered junctions are unavoidable, as the primary cause of accidents concerns the vehicles making the right hand turn from the major road, central islands should be considered for providing a safe waiting area in the centre of the major road. (See paras 286, 379(e) and 382 (Fig 45).)

Frequency of Junctions

425. It is desirable to restrict the number of side road junctions on major roads to a minimum. It has been shown that accidents at a junction are approximately proportional to the square root of the product of the flows in each road. Accordingly it will be seen that by reducing two junctions to one the accident frequency should be reduced by about 30% and the position will be more advantageous where several roads are combined before joining a major route. It is, however, important to consider also the effect of traffic concentration by such an arrangement and to ensure that the design of the junction selected for feeding an area is adequate.

Accidents at Traffic Signal-Controlled Junctions

426. Examination of accident records sometimes shows that at certain signal-controlled junctions crossroad collisions occur frequently, particularly at times when traffic is light. It is usually found that either (a) detectors are too close to the junction for the speed of traffic or (b) the junction is not well balanced (i.e. the stop lines are at unequal distances from points of possible conflict); in addition, the clearance between traffic phases is too short. The situation is usually aggravated when visibility is restricted.

427. Attention should first be given to the siting of detectors (see para 314) but if this is satisfactory an improvement of the layout may be required. Where such an improvement is not practicable it would be appropriate to increase the clearance period between phases. This can readily be done with present day controllers, and often an increase of one second is sufficient; but no such adjustment is provided on older controllers (which give concurrent amber periods). The dangers can, however, be minimised by a small modification to such old controllers whereby the call from the first vehicle demanding the succeeding phase is made to extend the current phase. Where this modification has been made a substantial reduction in the number of crossroad collisions has been effected.

428. Good maintenance of signal equipment particularly of optical systems and detectors is also beneficial in reducing accidents. It is to be noted that faulty detectors causing congestion may also reduce the effective clearance between traffic phases with consequent possible danger.

PART 5

Assessment of Relative Merits of Alternative Schemes

General

429. The foregoing part gives many of the ways in which improvements in traffic flow and safety may be achieved either by short-term, medium or long-term measures. Information is also given as to the means of calculating traffic capacities and delays resulting from the various types of design.

430. In most instances, particularly for short or medium-term proposals, the choice is clear, but where there are alternatives such as between a traffic signal-controlled scheme, a roundabout or a scheme involving grade separation, or between widening schemes on different routes, a more detailed appraisal may be necessary.

431. In selecting the most appropriate scheme for a particular site it is first necessary to ensure that it has adequate traffic capacity to meet the growing needs of motor transport. Consideration must also be given to pedestrian facilities, amenity treatment and delay to vehicles.

432. In the simpler urban schemes where little or no redevelopment is involved economics may also help in the choice of the form a scheme should take or in determining the priority of different schemes. Although more work has yet to be done to clarify the basic assumptions made in economic assessment, it is possible to arrive at tentative economic valuations of the time lost to traffic through delays at junctions or along congested roads and also of the cost to the community of accidents. In larger urban schemes the possible effect of a road improvement on the development of an area should be taken into account and this may create problems in arriving at an economic assessment. In addition there are special problems in making economic assessments of schemes in urban areas due to the complex nature of traffic movements, choice of alternative routes, and near saturation of controlled junctions. The results from economic assessment should therefore be used with caution and they often serve best as a guide in considering alternative schemes or priorities rather than as a means of justifying a scheme financially.

433. The methods given below have been used, but as research is continuing it is advisable to consult the most up to date information available.

434. Reference has already been made to the methods of estimating delays at various forms of junctions, the

average speeds on urban roads under varying conditions, and the reductions in accidents from various types of improvement. From these factors the expected annual benefit resulting from an improvement can be evaluated, and after deducting any increase in cost in maintenance, compared with the capital cost of the scheme.

435. In many cases it may be found advantageous to divide a scheme into stages so that the highest economic benefit can be obtained, e.g. by constructing a roundabout initially which is designed so that a flyover or underpass can be added later.

Annual Benefit from Reduced Delay

436. Reduced delay may arise from the improvement of junctions or by reducing the journey time by improving roads. The annual benefit is then:

$$£\ \frac{\text{Savings in cost per vehicle per journey in pence}}{240} \times \begin{matrix}\text{Annual flow}\\ \text{in vehicles}\end{matrix}$$

The annual flow in vehicles may be taken as 365 × 12 × q where q is the average hourly flow (excluding two-wheeled vehicles) over a 12 hour day. (Although this accounts for traffic only during 12 hours of the day this is compensated for by including Sunday and early closing day traffic as for normal week days.)

437. The benefits are usually valued for conditions expected at the time of completion of the scheme—generally assumed to be five years from the initial design stage. This is effected by scaling up traffic flows, and from them estimating delays, journey times (and sometimes accidents) for the existing and improved layouts. It should be noted that the delay and journey times may increase more than in direct proportion to the increased traffic volumes.

438. Where savings in time along urban routes between intersections are to be calculated, reference should be made to Fig 31.

439. The actual values per vehicle assessed for vehicle hours and vehicle miles are affected by considerations such as taxation on fuel, and the value of non-working time. At present it is usual to exclude taxation and insurance and allow a value of 18s 2d per vehicle hour plus a flat rate of 4·4d per mile where comparison involves extra mileage. The cost per mile run is then $4{\cdot}4+\frac{218\text{d}}{v}$ per mile where v is the speed in miles per hour.

(These values are for 1963 and may need adjusting.)

Annual Benefit from the Reduction in Accidents

440. In para 399, Table 8, information is given as to the percentage by which accidents have been reduced by various types of road improvement schemes. Whilst the loss of life and human suffering cannot be evaluated, accidents are also a cost to the community in terms of damage, medical treatment, loss of output to those affected, etc. Use may be made of the following estimates of costs based on 1962 figures:

	£
a fatality	3,080
a serous injury	800
a slight personal injury	50
average cost of a personal injury accident	520
average cost of damage only accident	65

441. Since damage only accidents are inadequately reported, it is generally considered preferable to relate the cost of all accidents to the number of personal injury accidents. On this basis the cost of all accidents averaged over personal injury accidents was £650 in 1962.

442. In ascribing the benefits arising from the reduction in accidents the expected number based on the existing scheme and that for the improved scheme should be scaled up in proportion to the expected increase in traffic.

Assessment of Road Improvement

443. Whilst there are a number of methods of evaluation used throughout the world, in this country the rate of economic return is most commonly used, particularly for determining the priority of various schemes. This is determined as follows:

$$\begin{matrix}\text{rate of}\\ \text{return}\end{matrix} = 100 \times \frac{\text{Annual net benefits from reduced delay and accidents less extra annual maintenance cost}}{\text{capital cost of improvement}}\ \%$$

Example:

444. A section of urban road 30 ft in width and carrying an average volume over a 12-hour day (total for both directions) of 1,300 pcu's/hour (1,000 vehicles an hour) at an average speed of 18 mph is to be realigned and widened to 40 ft at a cost of £100,000. The length of the existing route is 0·5 miles and the new route 0·55 miles. The estimated cost of increased annual maintenance for the improvement is £1,000, the annual increase in traffic is taken as 5% compound interest. (See para 21.)

445. In five years' time the traffic flow will be increased to 1,660 pcu's an hour (1,276 vehicles per hour). From

Fig 31 the average speed for the increased flow on a 30 ft road would be 18 − 3·0 mph = 15·0 mph; for the 40 ft road with this volume of traffic the average speed would be 18 + 1·5 mph = 19·5 mph. The reduction in cost per vehicle journey =

$$0{\cdot}5\left(4{\cdot}4+\frac{218}{15}\right)-0{\cdot}55\left(4{\cdot}4+\frac{218}{19{\cdot}5}\right)=0{\cdot}90 \text{ pence}$$

Annual Saving =

$$\text{Annual flow}\times\frac{\text{Saving in cost per vehicle per journey in pence}}{240}-\text{Extra annual cost of maintenance}$$

Annual savings =

$$£365\times 12\times 1{,}276\times\frac{0{\cdot}90}{240}-£1{,}000=£19{,}958$$

$$\text{Rate of return}=\frac{19{,}958}{100{,}000}\times 100=20\% \text{ approximately}$$

(Accidents have not been taken into account in this example.)

For further reference see the following:

'The Economic Assessment of Returns from Roadworks', by G. Charlesworth and J. L. Paisley. (Proceedings Inst. C.E., November, 1959.)

'Road Improvements; Choosing Priorities by a New Formula', by G. Charlesworth, D. G. Reynolds and J. G. Wardrop. (Engineering 1959, 188 (4873).)

'Vehicle Operating Costs in 1962', R. F. F. Dawson. (Traffic Engineering and Control, January 1963.)

The Assessment of Priority for Road Improvements. Road Research Technical Paper No. 48 – Her Majesty's Stationery Office.

Comparison of Alternative Types of Road Junction

446. The choice between alternative schemes for an intersection is primarily dependent upon the following factors;

(a) Site conditions. Physical layout, relative ground levels and availability of additional land are usually the deciding factors in the choice of a suitable scheme. Within the limitations imposed by these factors alternative schemes can be tested against traffic requirements. Particularly in the case of channelised or complex designs and roundabouts the form taken is much influenced by using the site to its best advantage.

(b) Character of a road. The character of a road has a large bearing on the choice of junction design. In city streets traffic signals are appropriate at most major junctions except those key junctions to which displaced right turning traffic can be diverted and for which roundabouts are more suited. On other major routes consideration should be given to roundabouts rather than signal control. Grade separation is essential on an urban motorway whilst on other routes its application is dependent on whether (a) it is needed in order to provide for sufficient capacity or (b) it is economically justified in terms of savings in traffic delay and accidents.

(c) Traffic volumes and turning movements. Whilst the dimensions of a scheme depend mainly on traffic volumes, turning movements have a most important bearing on the most appropriate design. The choice between a roundabout and traffic signal control largely depends on land availability and turning movements. When turning movements are small the advantage generally lies with traffic signals, but as the volume of turning movements increases the capacity of roundabouts increases and that of simple signal-controlled intersections decreases. Where the proportion of turning movements exceeds that which simple signal control can accommodate, or where the intersection is more than 4-way the choice lies between the roundabout, the channelised or complex signal-controlled system or grade separation.

(d) Ratio of peak to average flows. Where traffic flows have a high peak to average ratio (usually more than 1½ to 1 on a 12-hour census) the roundabout may have considerable advantages over signal-controlled system by minimising delays throughout most of the day. This does not, however, apply where there are already signals on the approach road and an appropriate system of linking can be installed. If the peak flows are frequently likely to exceed the design capacity of a roundabout it is necessary to consider a signal-controlled system.

PART 6

Follow-up Studies

Statistical Significance of Improvements

447. When improvements have been carried out it is particularly desirable to carry out 'after' studies as to accidents, traffic volumes, speeds and delays on the same basis as 'before' studies described in Part 2. This is necessary so that:

(a) Unforeseen problems may be shown up and minor adjustments made, for example, re-timing of signals, etc.

(b) The scheme carried out may be judged as to its adequacy or otherwise to meet future traffic growth and if necessary, future proposals planned.

(c) Examination of accident records under the new conditions may point to new or further modifications.

448. The accuracy of 'before' and 'after' studies for determining journey times, speeds or delays is dependent on the variability of results and the number of tests taken.

449. The results of 'before' and 'after' studies should be subjected to a test of statistical significance; that is, any apparent change, such as an increase in journey speed, should be tested to find out whether the change could have arisen by chance when underlying conditions had not in fact changed. Statistical tests of significance conventionally assess results at the 5% level of probability. i.e. a change is significant at this level if the odds are 19 to 1 against it occurring by chance.

450. A simple method for testing speed changes is to pair successive speed measurements as taken and for each pair subtract the smaller from the larger. This is done for the before and after speeds and the average of all these differences, i.e. both before and after, is then obtained. This average difference is then multiplied by $1{\cdot}8\sqrt{\frac{1}{n}+\frac{1}{m}}$ where n and m are the number of speed measurements taken before and after. If this result is less than the difference between the average of the speeds occurring before and the average of the speeds occurring after, then the change in average speeds is unlikely to have occurred by chance and can be regarded with confidence.

451. When changes in accidents are tested the numbers involved are in statistical terms, small and accident records over long periods both 'before' and 'after' a change has been made are needed to establish reliable conclusions.

452. To determine whether there has been a statistically significant improvement in the accident record, the following test may be applied:

453. If b is the number of accidents occurring before an improvement and a the number of accidents in an equal and comparable period after an improvement then if the reduction in accidents $(b-a)$ is greater than twice $\sqrt{a+b}$, the change is statistically significant (at the 5% level) and the improvement can be regarded as a real one.

454. The foregoing test assumes that there is no upward or downward trend in accidents over the period when accident records were taken. If this is unrealistic it is necessary to use as a 'control' the number of accidents in an area not affected by a traffic scheme, this can usually be the local authority area or police district. In this case a change is statistically significant (at the 5% level) where

$$N\left[\left(\frac{b}{a+b}-\frac{c}{c+d}\right)\times\left(\frac{b}{b+c}-\frac{a}{a+d}\right)\right]$$

is greater than 3·8, where b and a are the numbers of accidents occurring 'before' and 'after' at the site concerned and c and d are the numbers of accidents occurring 'before' and 'after' for the control area and N is the total number of accidents $(a+b+c+d)$. For this purpose the 'before' period need not be equal to the 'after' period. This formula should not be used if the smaller of $(a+b)$ and $(c+d)$ multiplied by the smaller of $(b+c)$ and $(a+d)$ is less than 5 N. In such cases, reference should be made to Biometrica, Vol 35, 1948, pages 145–156, The Fisher-Yates Test of Significance in a 2×2 contingency table by D. J. Finney and to Biometrica, Vol 40, 1953, pages 74–86, Test of Significance in a 2×2 contingency table – extension of Finney's table by R. Latsha.

455. If a specific type of accident is being considered such as pedestrian accidents, then the numbers taken for the control area should be for the same type of accident.

456. For further guidance on methods of statistical analysis reference should be made to standard works.

Adequacy of Measures Carried Out

Banning of Right Hand Turns

457. Whilst site inspection at peak times may be adequate to judge the improvement effected, 'before' and 'after' traffic volumes and delay studies should generally be carried out.

458. The major disadvantage of this form of restriction is that sometimes unforeseen displacement of turning traffic to other junctions causes congestion. In such circumstances it may be necessary to extend the scheme to other junctions or to improve alternative routes either by better signposting or by one-way working in a side road.

One-way Streets

459. As an appearance of improvement produced by a one-way street system can be misleading it is usually desirable to make a close assessment both of the increased traffic capacity of the system as a whole and the effect on traffic delays. With regard to safety, measures can usually be taken to meet particular problems such as by installing extra traffic signals for pedestrians. Checks should be made as to the possible adverse effects on roads outside the system. For example, where a one-way system is running north and south, there is a tendency for parallel routes lying east and west of the system to carry extra traffic northwards and southwards respectively.

460. When examining the changes in capacity it is desirable to cover the whole network so that the improvement to roads crossing the system may be gauged, but more particular attention should be given to that of key junctions.

461. The assessment of overall delay to traffic can be made by taking journey times throughout the system between points that are sufficiently outside the area not to be directly affected. A few journey times to and from points within the area should also be measured. Traffic counts should also be taken on the periphery to the system and an estimate made of the proportion of terminating traffic so that a comparison may be made in total delay (vehicle-hours) occurring before and after the one-way system is introduced.

462. The effects of a scheme must be considered before deciding whether it should be made permanent. Adverse effects on public transport services, inconvenience to pedestrians and to business should also be taken into account particularly when gains to traffic are small.

Waiting Restrictions

463. Site inspection and 'before' and 'after' studies will show the improvements in traffic flow from waiting restrictions. In some cases, it may be found that:

(1) Displaced vehicles parking elsewhere are causing congestion and extra parking facilities and/or further restrictive measures are needed.

(2) Traffic is still being impeded by vehicles loading and unloading and a ban may be necessary during peak periods.

(3) The times at which waiting restrictions apply require modification.

Road Safety Measures

464. Detailed accident records will indicate the degree of success in effecting greater safety. These records require study at regular intervals (6 or 12 monthly) where improvements have been carried out, to determine whether further measures are required. Owing to possible chance variations it is difficult to reach firm conclusions on measures adopted until accident records over a long period are available. (See paras 451–456.)

Major Improvement Schemes

465. Where a road or key intersection has been improved the 'after' survey will usually reveal an abnormal growth of traffic arising (a) on account of traffic returning from previously used alternative routes (b) due to traffic adopting a new route to include the area concerned in preference to congested routes and (c) due to generated traffic.

466. The reserve capacity of the improvement should be recalculated so that future improvements may, if necessary, be allowed for in the development plans and road programme. In some cases it may be found that the programmed improvement for existing routes is unlikely to meet future requirements and consideration should be given to the planning of new routes.

Car Parking Accommodation

467. The periodic surveys of parking may reveal that both on or off street car parking accommodation which has been provided is not adequate and adjustments should be made in development plans for the inclusion of additional accommodation to meet these requirements.

Minor Adjustments to Schemes

468. Schemes involving signal control require particular consideration both when the scheme is brought into operation and at subsequent intervals thereafter so that the signal settings may meet traffic requirements. Alterations in traffic distribution, e.g. an increase in right turns, may make it worthwhile to change the siting of refuges.

469. Where roundabouts are constructed, minor adjustments may be required to the traffic guide islands at the entry points, and temporary layouts of guide islands are generally advantageous so that adjustments can be made to obtain the best alignment to assist the weaving of traffic streams.

470. In the case of junction improvements where traffic movements are complex it may be found that drivers take unexpected paths and that either additional carriageway markings or some modification to traffic signs is required to overcome such problems.

471. Although there may be some reluctance to make minor adjustments to schemes after their inception, in view of the possibility of public criticism, this should not be allowed to act as a deterrent if it is clear that they would be advantageous to traffic.

PART 7

Conclusion

472. Traffic Engineering is increasingly replacing personal judgment with calculation and tested knowledge. Much more information is needed to improve the precision with which it may be applied but it is already providing in the hands of increasing numbers of engineers a quantitative means for assessing traffic requirements, enabling the best use to be made of existing roads, and designing traffic systems to meet the requirements of a town.

473. A memorandum of this kind cannot be comprehensive and the training of engineers is essential if they are to apply general techniques to particular cases.

474. New methods of meeting traffic problems such as new types of signal-controlled pedestrian crossings, 'give way to traffic from the right' signs at roundabouts, use of vehicle presence detectors, tidal traffic working and area traffic control will continue to come into use as their possibilities are explored. Increasing application will no doubt be made of pedestrian segregation, channelisation, urban motorways and grade separated systems.

475. With regard to short-term measures much relief of congestion can be obtained at little cost; waiting restrictions, banning of right turns, or one-way systems will often increase road capacity by 20% or more. Greater improvement (20–50%) can often be effected at signal-controlled junctions, by rephasing and simplifying the traffic pattern, by restricting certain movements, or by small carriageway widenings at the signal approaches. Increasing use can be made of the more flexible modern traffic signal controllers to meet peak-hour demands. Although there is no short-cut to eliminating traffic congestion much can be done by detailed study of each problem and by applying suitable techniques.

476. With medium term measures the emphasis should be on junction improvements, provision of roundabouts, new signal-controlled junctions and the widening of roads particularly at junctions or bottlenecks. In narrow streets, lay-bys provided for buses and delivery vehicles can be of great value in promoting freer flow conditions.

477. From the safety aspect whilst measures such as traffic signs, carriageway markings and guard rails will meet particular problems, more extensive schemes such as the realignment of carriageways, improvement of visibility at junctions, and pedestrian subways, will be found necessary to meet others.

478. For longer-term measures which require to be programmed in order of priority, help can be obtained from Traffic Engineering techniques in determining priorities and in designing the various schemes for the new or improved roads, junctions and general road

layout to meet the future requirements of a town. In this connection it will, of course, be appreciated that the process of establishing environmental areas, by freeing them of unnecessary traffic and thereby making them pleasanter and safer places to live and work in, will increase traffic on the primary road network which will have to be designed to take the heavier traffic flows. At the same time the full use of traffic engineering techniques will be required to ensure that so far as is reasonable the roads and junctions are so well located and designed that their capacities are appropriate for traffic requirements.

479. With reagrd to the development plan for a town, traffic engineering techniques can help to ensure not only that the traffic plan meets the needs of a town but also that it takes a form which leads to a satisfactory and economic traffic system.

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Ministry of Transport/Scottish Development Department

ADVISORY MEMORANDUM ON

Urban Traffic Engineering Techniques

LONDON: HER MAJESTY'S STATIONERY OFFICE
1965

FOREWORD BY

THE MINISTER OF TRANSPORT

THE RT. HON. TOM FRASER, M.P.

Traffic engineering is a growing branch of highway engineering and becoming increasingly important. It enables the best use to be made of existing streets; it enables schemes for road construction and improvement to be more accurately designed for the traffic which will use them.

This Memorandum is to meet the demand for information about traffic engineering techniques that are suitable for applying in towns.

Everyone is aware of the problems of traffic; no-one can escape their effects. There is no single remedy, and whether we are dealing with immediate or long-term solutions, the need is firstly for close study of the problems and secondly for the application of the best possible measures to deal with them.

The Buchanan Report on 'Traffic in Towns' emphasises that urban traffic and the buildings and land uses which generate it are two sides of the same situation. By enabling road systems to be designed to meet future traffic needs more effectively, traffic engineering can make a basic contribution to the whole planning of urban redevelopment.

I hope that traffic engineers will find much in this Memorandum to help them both in this long-term task and in the more immediate job of coping with traffic under present-day conditions.

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